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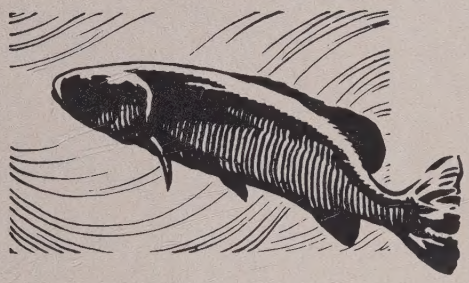

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THE MISSING LINKS OF FISH HUSBANDRY

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TWO KINDS OF KNOWLEDGE are demanded for efficiency in hatchery management of artificial fish propagation. The first is fundamental knowledge gained through basic research in such fields as disease, nutrition, biochemistry, physiology, and genetics. The second is gained through pilot-plant studies wherein the "test-tube" results of basic research are adapted to production problems. The tool that management uses to check on the application of research knowledge to production is called quality control.

The sequence in which these three items are presented is not accidental. Before an applied-research problem can be undertaken in the pilot plant, the fundamental research on which it will draw must have been done. Before a quality-control program can be meaningful, research must not only define the quality to be controlled but also devise methods for the demonstration of this quality.

Basic research is now receiving some much-needed attention. For the present, the other programs--pilot plant and quality control--are largely missing links in the chain of events that connect the search for knowledge with its application. The purpose of this paper is to examine the role of and interrelationship between basic research, applied research, and quality control in sufficient detail to illuminate the need for filling in these missing links.

Basic Research

The primary goal of basic research is to supply necessary fundamental knowledge of the subject studied. It may be directed, that is, have an obviously applicable objective such as nutrition or disease investigations; or it may be non-directed. If the research is non-directed, the immediate applicability is not always obvious. Although this discussion will be concerned primarily with directed research, we should not slight the importance of non-directed research. Indeed, this forms the basis for solution of future problems and is, in fact, the stuff on which directed research feeds. Thus, while all may see a crowning achievement of directed research such as the polio vaccine, we should realize that the knowledge which made it possible was drawn from literally thousands of non-directed, basic research projects.

Fundamental research in nutrition is responsible for determining the qualitative and quantitative nutritional requirements of the particular species of fish in terms of the basic nutrients--vitamins, amino acids, carbohydrates, fatty acids, and inorganic elements. This sounds imposing. More simply, what it means is that certain basic nutrients must be supplied by the diet if normal growth and health are to be maintained. These are essential nutrients, indispensable components of the diet. Other nutrients, though used for growth, can, if adequate starting materials are available, be synthesized by the body in sufficient amounts to meet its needs. For instance, of the 20 to 25 amino acids which are the building block of the body's protein, 10 have been classified as essential to young chinook salmon

(Halver 1957b). The other amino acids used in protein synthesis by the experimental fish during their growth were synthesized by the fish as needed.

A brief survey of nutritional requirements of animals which have been studied in much greater detail will perhaps throw some light on additional directions that fish nutrition research must take.

It is known that amino acid requirements vary both qualitatively and quantitatively with the different species investigated, and that within a given species the quantitative requirements change with age and with other factors that influence body demands (Maynard 1951). The same story is repeated with the other basic nutrients. Of the many fatty acids which compose fats, only three are known to be required for most species studied (Maynard 1951). Of the 16 currently recognized vitamins, some animals are known to require as many as 15, whereas other animals need fewer than 10; and of the inorganic elements, 16 are recognized as essential, again with species differences (Spector 1956).

It should be apparent that basic nutrition research must answer many questions for fishery management. Some of the questions that must be answered for any species being considered for production and management are: What are the nutritional requirements in terms of basic nutrients? How do these requirements vary with age and/or physiological state? How do water temperature and chemistry, as well as other external factors, affect the requirements? What are the symptoms of specific nutritional deficiencies, and how can they be detected at an early stage? As these and other questions are answered by basic nutrition research and adapted where necessary by applied studies, the productivity and efficiency of hatchery propagation will be increased.

Closely allied with directed nutrition research is fundamental research in the biochemical function of nutrients in general metabolism. A thorough knowledge in these fields is essential to interpret nutritional disorders and disease syndromes. Such studies form the rationale for the important biochemical tests that are necessary for the early detection of nutritional deficiencies.

That a histological description of normal and abnormal fish tissues is a valuable tool for the detection and description of pathological conditions has been amply demonstrated by numerous publications from this laboratory (Wood, Snieszko, and Yasutake, 1955; Wood and Yasutake 1956a, 1956b, 1956c, 1957). In studies on other animals the histological technique has proved its value as a tool for the detection of nutritional deficiencies (Follis 1948).

The importance of physiological and genetic research in the understanding and improvement of the species of hatchery-reared fish cannot be overemphasized. However, because these phases of basic research will have only minor counterparts in either pilot-plant or quality-control functions, further discussion of these points is not considered within the scope of this paper.

The Pilot Plant

Historically the function of a pilot plant has been to test and adapt research findings to production. Its importance has long been realized and applied by all forms of industry. For illustrative purposes let us assume that an industrial research chemist has developed a method for producing a new synthetic fiber. The pilot-plant staff must now adapt his laboratory method to a production scale, using available crude materials rather than laboratory chemicals. They must determine the effect of impurities in the starting materials on the finished product and devise means of compensating for or eliminating harmful effects. Only after all of the "bugs" have been worked out of the method is it ready to be turned over to production.

A pilot plant for fish nutrition studies would perform similar functions. Almost without exception, purified diets must be used for the determination of basic nutritional requirements. Before the results can be applied to a production diet, we must know not only how much of these

various nutrients is in our dietary ingredients, but also how much of these are available to the fish that eats the diet. Using the species of fish concerned, each proposed dietary ingredient must be biologically assayed for digestibility and availability of nutrients and the biological value of proteins determined. Using the data from biological and chemical assays, diets can then be compounded to meet specific requirements as determined by nutritional research. These diets would then be evaluated by standard feeding-trial methods on a pilot-plant scale. As the results from the pilot plant must serve many production stations having variable conditions of water temperature and chemistry that affect nutritional requirements, there would have to be facilities available to conduct the tests under a wide range of environmental conditions.

The techniques of this phase of the pilot plant are those of nutritional research. Thus, for successful operation, the pilot plant must have key personnel who are thoroughly trained in the precepts of modern nutritional research.

Similar pilot-plant functions to complement fish disease research can be envisioned. Methods similar to the medical profession's familiar clinical trial for the testing of research-developed therapeutic and preventive agents are, in fact, being employed by fish-disease investigators. If the facilities of a pilot plant were available, workers in basic disease research could be freed of much of this routine and thus would be able to devote more time to fundamental problems of fish diseases.

Quality Controls

In industry a quality-control unit functions as follows: the incoming raw materials with which their product is made are analyzed so that changes in quality can be compensated to prevent adverse effects on their product, and the product itself is continuously checked to assure that it meets previously assigned standards.

A similar process is indicated for quality control in hatchery management. Each lot of the diet materials should be assayed so that changes in diet formulation can be made as necessary. Using the "quality-detecting" tools provided by research, the fish reared could be checked at frequent intervals to assure that they meet the required standards. As previously mentioned, some of these tools include: histological analysis for the detection of nutritional deficiencies and other pathological conditions, other methods for the detection of diseases, and biochemical tests for the elucidation of specific nutritional deficiencies. Continued research will provide additional tests of desirable fish quality.

Discussion

The research data of Halver and DeLong (Halver 1957; Halver, DeLong, and Mertz, 1957, 1958; DeLong, Halver, and Mertz, 1957) on the vitamin, amino acid, and protein requirements of chinook salmon and numerous investigators' data on the vitamin requirements of trout (summarized by Phillips and Brockway, 1957) should be adapted and applied to production diets immediately. Basic research in nutrition and disease is continuing at an expanded rate; and as additional values are obtained, they, too, must be applied. Both pilot-plant and quality-control programs are, therefore, needed.

Integration of basic research, pilot-plant, and quality-control programs is of utmost importance. To prevent duplication of effort and to effect close coordination, it would seem most efficient to have part of the pilot-plant functions and quality control together in a joint pilot-plant and quality-control laboratory, even though the pilot-plant operation is a research function while the quality-control program is normally one of management. Some of the pilot-plant functions have need for the tools and equipment of basic research, and logically these should be included with the present basic research organizations.

Summary

Criticism notwithstanding, basic research is not undertaken just for the sake

of doing something. Research in fish nutrition and diseases can put fishery management on the same firm footing that is enjoyed by other animal husbandries. Of major importance in the accomplishment of this goal will be the establishment of a combination pilot plant-quality control laboratory. The functions of this unit would be twofold: First, to adapt, where necessary, the findings of basic research to the problems of hatchery propagation; and second, to utilize the quality-detecting tools developed by basic research to maintain the quality of the fish produced.

Literature Cited

DeLong, D. C., J. E. Halver, and E. T. Mertz
1957. Protein requirements of chinook salmon at two water temperatures. Fed. Proc. 16 (1): 384, No. 1644.

Follis, R. H.
1948. Pathology of nutritional diseases. 291 pp., illus. C. C. Thomas Co., Springfield, Ill.

Halver, J. E.
1957. Nutrition of salmonoid fishes. III. Water-soluble vitamin requirements of chinook salmon. Jour. Nutri. 62 (2): 225-243.

------ D. C. DeLong, and E. T. Mertz
1957. Nutrition of salmonoid fishes. V. Classification of essential amino acids for chinook salmon. Jour. Nutri. 63 (1): 95-105.

1958. Threonine and lysine requirements of chinook salmon. Fed. Proc. 17 (1): 478, No. 1873.

Maynard, L. A.
1951. Animal nutrition. 3d ed., 474 pp., illus. McGraw Hill Book Co., New York.

Phillips, A. M., Jr., and D. R. Brockway
1957. The nutrition of trout. IV. Vitamin requirements. Prog. Fish-Cult. 19 (3): 119-123.

Spector, W. S.
1956. Handbook of biological data. 584 pp. W. B. Saunders Co., Philadelphia.

Wood, E. M., S. F. Snieszko, and W. T. Yasutake
1955. Infectious pancreatic necrosis in brook trout. Arch. Path. 60: 26-28.

------ and W. T. Yasutake
1956a. Histopathology of kidney disease in fish. Am. Jour. Path. 32 (4): 845-857.

1956b. Histopathologic changes of a virus-like disease of sockeye salmon. Trans. Am. Microsc. Soc. 75 (1): 85-90.

1956c. Histopathology of fish. III. Peduncle ("cold-water") disease. Prog. Fish-Cult. 18 (2): 58-61.

1957. Histopathology of fish. V. Gill disease. Prog. Fish-Cult. 19 (1): 7-13.

Samples that were taken during June 1958 from a Louisiana lake (surface area, 1,044 acres; average depth, 11 feet; maximum depth, 25 feet) indicated a total production of 203 pounds of fish per surface acre of water. Gizzard and threadfin shad made up 149 pounds (73 percent) of this production. Similar samples that were taken after the application of rotenone to the lake showed the presence of slightly more than 7 pounds of shad per surface acre of water, or a kill of more than 95 percent of the original shad production.

FIELD TESTING ROTARY FISH SCREENS IN NORTHEASTERN OREGON

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WATER FROM UPPER COLUMBIA RIVER TRIBUTARIES has been diverted extensively for irrigation in northeastern Oregon, resulting in tremendous annual losses of migrating salmonid fingerlings. Since about 1925 the Oregon State Game Commission has been concerned about the screening of ditches and canals where fish losses occurred. In 1941, Oregon law finally gave the Commission authority to screen diversions up to 8 feet in width.

To justify a rapidly expanding screening program, the general usefulness of rotary screens for bypassing fish was field-tested throughout five irrigation seasons, from 1952 through 1956.

Recorded field data were used to determine: (1) the seasonal effectiveness of certain screens, (2) the validity of estimating total number of fish saved within a watershed where all diversions are screened, (3) the future use of various screen mesh sizes, and (4) improved schedules for screen maintenance.

Other authors have described various screens, their general operational efficiency and differences (Wales, Murphey, and Handley, 1950; Leitritz 1952; Whalls, Shetter, and Vandett, 1957). Usually these authors were introducing a new type of screen, presumably better. In Oregon considerable effort has been made to improve the rotary reverse-drive screen.

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In four northeastern Oregon counties, more than 200 rotary screens have been in operation since 1950 (figure 1). About ten new and replacement screens are installed annually. No two diversions or screen installations are exactly alike; and variations in diversion width, volume, velocity, angle of take-off, and headgate location constitute separate problems in installation and maintenance.

The Oregon State Game Commission has manufactured and used the rotary-type, reverse-drive screen since 1945. The width of screens ranges from 2 to 8 feet. Galvanized 14- or 16-gauge wire, 4 or 5 meshes to the inch, is wrapped on steel drum bands to obtain cylindrical perfection. After the diversion volume and velocity have been calculated, a concrete box is poured to house the screen, reverse gears, and paddle wheel (figure 2).

A screen installation without a bypass for migrant fish is useless. Although only a small amount of water is required for a bypass, that amount is absolutely essential (Leitritz 1952). The best device for returning diverted fish to Oregon streams was found to be a 2-inch pipe, embedded through the concrete box wall at a point just forward of the screen and at the level of the box floor. The outlet end of the pipe is inserted into a 4- or 6-inch tile to provide fish with a passage to the stream.

The installation of small screens (2- to 6-foot) is accomplished by using rubber side- and bottom-sealing flaps, the loose edges of which are held by water pressure against the moving screen. Larger

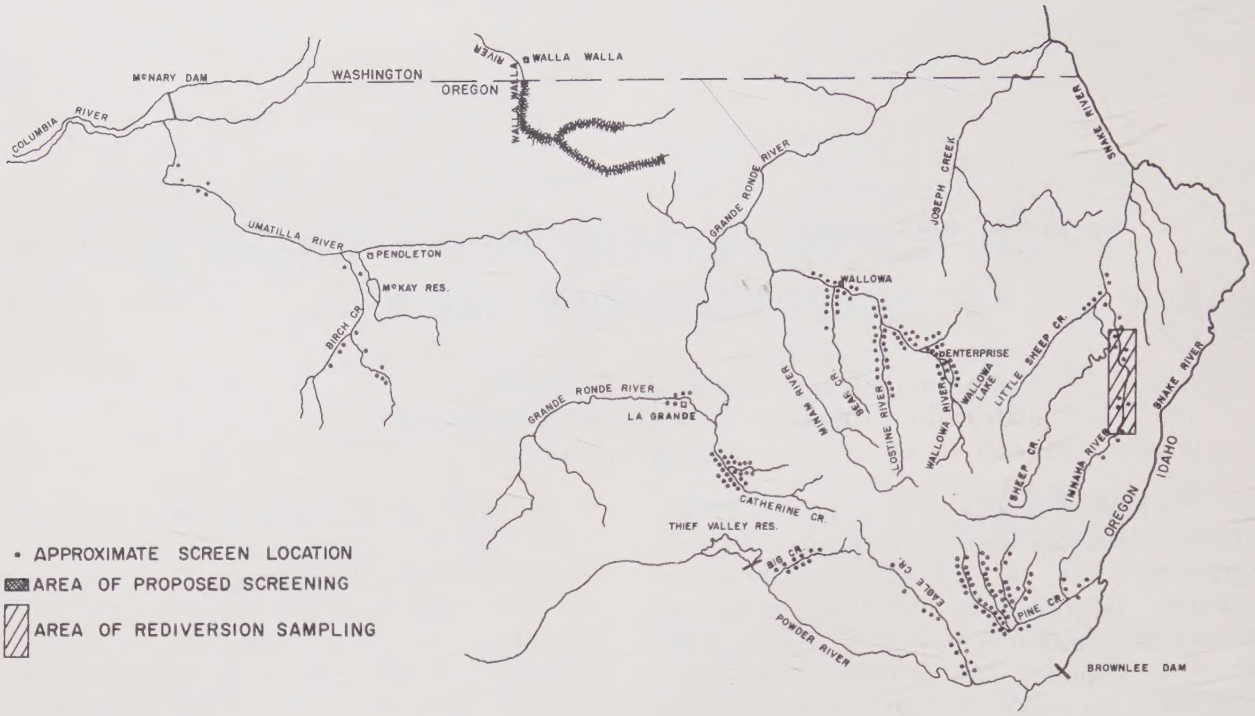


FIGURE 1.--The distribution of 230 fish screens in 6 watersheds of northeastern Oregon.

screens are "cradled" in an angle-iron frame with rubber seals built in on both sides and along the bottom. The installation of large screens requires the use of A-frames and chain hoists. About 1,000 rotary screens have been installed in irrigation diversions throughout Oregon, including the recent John Day River project of nearly 450 screens.

Methods Used in Trapping Migrants

Small, movable live boxes were placed at the ends of bypass pipes to trap migrants at test diversions (figure 3). One concrete live box was installed permanently on the bypass of a large diversion leading from the Umatilla River. Thousands of migrating steelhead trout are trapped and transported to the Columbia River, 15 miles downstream, because of frequent low flow.

The length of the period of screen operation ranged, depending upon the water use, from 30 to 200 days. The numbers and species of the trapped fish were recorded when the screens were visited by maintenance personnel. Generally, counts made at the test screens at 1-, 2-, or 3-day intervals were recorded by weekly intervals for the sake of simplicity.

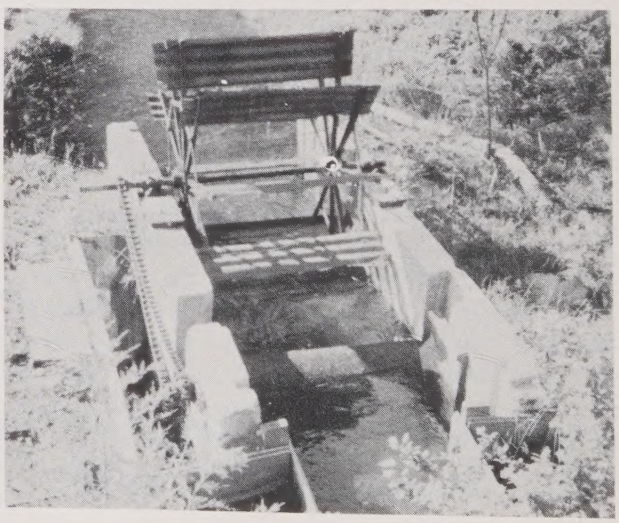


FIGURE 2.--Typical rotary screen installation. Note reverse drive gears and corregated aluminum paddles.

Results of Screen Bypass Trapping

Some diversions carry water all year for livestock and irrigation. Only five "year-round" ditches offered an opportunity to determine the extent of early spring migration occurring before the general irrigation season (table 1).

Wales (1948) found that the downstream movement of the steelhead trout began in April or early in May and reached a peak in June on some Klamath River tributaries in northern California. He also noted a September migration of steelhead trout fingerlings in Beaver Creek, tributary to the Klamath. Sumner (1953) reported steelhead trout at a downstream weir on Sand Creek, a coastal stream in Oregon, from mid-March to mid-June, with the migration peak occurring about May 1.

Continuous trapping in many diversions from 10 streams in northeastern Oregon revealed that peaks in downstream migration of steelhead trout and chinook salmon occurred in May, June, August, September, and October. Though numerous fish species migrated, only chinook salmon and steelhead trout were recorded (table 2).

Early in the screen-testing program, maintenance personnel noticed many migrant fishes in diversions leading from the stream at a narrow angle. The assumption that fish were generally diverted in an inverse proportion to the number of degrees in the angle of take-off was tested at 19 rotary screens. Diversions built at an angle of less than 30° to the stream attract, on the average, three times as many migrants as ditches with divergence angles exceeding 30°.

FIGURE 3.--Operating screen, bypass pipe, and trap box on a diversion of the Imnaha River.

The effect of diversion width upon fish attraction was also tested. Evidence that the least angle of diversion take-off is more attractive to fish than diversion width alone is recorded in tables 3 and 4.

Results of Screen-Efficiency Sampling

Efficiency sampling was done periodically at 8 different screens (4 mesh to the inch) over a 4-year period during which simple field techniques were employed.

Fyke nets lined with bobbinet were put in a diversion directly behind the paddle wheel after the possibility of there being fish behind the screen had been eliminated by electrical shocking or rotenone poisoning. Board wings were set from the fyke net to the ditchbank as needed. Four- and

TABLE 1.--Early spring migration of steelhead trout and chinook salmon at five rotary screens, 1953

Stream	Screen number	Date	Migrants bypassed to May 31	Total fish bypassed in 1953	Percentage bypassed before May 31
Wallowa River--	8-64	Mar. 5 - May 31	2,096	2,539	82
Eagle Creek----	9-23	Mar. 24 - May 31	752	3,538	21
	9- 6	Apr. 1 - May 31	732	5,185	14
Catherine Creek	8-101	Apr. 22 - May 31	244	388	63
	8-104	Apr. 21 - May 31	217	320	67

TABLE 2.--Monthly catches of downstream-migrating chinook salmon and steelhead trout at six rotary-screen bypasses, 1952-56

Stream	Screen number	Year	Catch during month[1]								Total
			Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	
Umatilla River	7-61	1952	----	467	7,577	3,329	6	------	------	------	-----	11,379
		1953	33	1,078	5,681	865	----	------	------	------	-----	7,657
		1954	----	2,385	26,723	3,577	----	------	------	------	-----	32,685
		1955	92	1,072	1,662	3,450	----	------	------	------	-----	6,276
		1956	----	156	3,219	2,575	----	------	------	------	-----	5,950
Imnaha River--	8-88	1952	----	-----	------	55	540	4,425	1,852	787	-----	7,659
		1953	----	-----	------	36	182	10,374	12,924	126	-----	23,642
		1954	----	-----	------	-----	446	754	799	338	-----	2,337
		1955	----	-----	------	39	926	10,146	17,252	3,844	-----	32,207
		1956	----	-----	------	-----	179	4,710	6,827	2,736	-----	14,452
Wallowa River	8-64	1952	----	-----	907	211	47	44	44	45	17	1,315
		1953	630	499	967	317	35	33	43	15	-----	2,539
		1954	36	42	297	91	58	24	36	37	-----	621
		1955	----	374	1,825	339	106	70	172	124	-----	3,010
		1956	----	-----	947	175	16	12	10	2	-----	1,162
Lostine River	8-17	1952	----	-----	------	-----	12	1,395	1,530	469	76	3,482
		1953	----	-----	27	16	13	646	949	650	-----	2,301
		1954	----	84	48	34	26	1,301	1,672	------	-----	3,165
		1955	----	-----	16	18	48	1,686	4,082	366	-----	6,216
		(2/)	----	-----	------	-----	----	------	------	------	-----	------
Eagle Creek---	9-6	1952	----	-----	333	233	170	316	1,543	1,608	1,494	5,697
		1953	----	413	319	483	163	222	929	2,656	-----	5,185
		1954	----	415	205	215	613	510	1,449	8,803	881	13,091
		1955	----	64	58	77	185	370	345	2,133	-----	3,232
		1956	----	-----	61	151	192	84	114	505	-----	1,107
Eagle Creek---	9-23	1952	----	-----	43	57	91	194	1,378	1,898	848	4,509
		1953	239	259	154	114	95	248	948	1,381	-----	3,438
		1954	119	580	107	170	430	568	1,976	10,610	3,100	17,660
		1955	----	663	553	111	216	820	1,675	4,246	-----	8,284
		1956	----	-----	319	213	407	171	227	2,751	-----	4,088

1/ Peak migration numbers underlined.

2/ Work discontinued in 1956.

TABLE 3.--Averaged bypass catches in relation to the angle of diversion take-off

Degree of take-off angle from stream	Number of screens sampled	Average number of fish bypassed	Significant differences [1]
0 - 10	7	2,162	‖
10 - 20	3	1,400	‖
20 - 30	3	1,794	‖
30 - 45	4	529	‖
45 - 90	2	201	‖

[1] Averages which are not covered by the same line are significantly different, P = 0.01 (Duncan 1955).

TABLE 4.--Averaged bypass catches in relation to diversion width

Screen size (inches)	Number of screens sampled	Average number of fish bypassed	Significant differences [1]
34 - 58	6	1,554	‖
60 - 84	8	1,300	‖
86 - 132	5	1,380	‖

[1] Averages which are not covered by the same line are significantly different, P = 0.01 (Duncan 1955).

six-foot-square fykes precluded adequate sampling in the larger diversions.

All sampling was done over a 15-hour period, from 5 p.m. to 8 a.m. By comparing the fyke-net catch with the bypass trap catch over the same period, percentage of fish loss through, over, or around the screen was recorded (table 5).

Several times the presence of fish in a fyke net was due to slight defects in side and bottom screen seals. At one screen (No. 8-88) on the Imnaha, a 15-percent loss through the screen was recorded in one night. A defective side seal was repaired, but a 3-percent loss occurred the next night. After the faulty seal was replaced with a new seal, a third test revealed no loss among 944 chinook fingerlings bypassed in the usual 15-hour period.

In Oregon we are replacing large-meshed screen with small-meshed screen in upper tributaries where very small steelhead fry have been known to pass through screens with 0.25-inch openings.

Re-Diversion Experiments, Imnaha River

Marking by tattoo was used to provide a basis for fish-population estimates and to determine subsequent proportions of

TABLE 5.--Efficiency of four-mesh-to-the-inch screen sampling at eight installations, northeastern Oregon

Stream	Screen number	Number of samples	Total fyke-net catch behind screen	Bypass trap catch	Percentage successfully bypassed
Imnaha River------	8-88	4	92	4,289	98
	8-78	1	0	1,193	100
Pine Creek--------	9-92	3	[1] 36	261	88
Eagle Creek-------	9- 4	1	0	350	100
	9- 6	1	0	46	100
Lostine River-----	8-17	2	7	110	94
	8- 2	2	[1] 105	26	20
Bear Creek--------	8-16	1	2	24	92

[1] Steelhead fry, 1 to 1.25 inches in length.

migrants being diverted and re-diverted from the stream into irrigation ditches. Both battery and generator types of tattoo equipment were used in the field. The battery model, designed by George Eicher in 1956, was used at screen No. 8-78; the improved generator-type tattoo machine (Chapman 1957) was used with a 110-volt generator at screen No. 8-88. Chloretone solutions provided anesthesia.

Of the 24,793 migrants trapped in a 68-day period at two upper screens on the Imnaha River, 20 percent were marked. Recoveries were made at two screen by-pass traps, 14 and 15 miles, respectively, lower on the river. (See figure 1.)

Population estimates were made for the period from August 1 to mid-October, the normal migration period for chinook fingerlings in the Imnaha River. The formula $x = \frac{a}{b} y$ (Schaefer 1951) was used to estimate total populations in the river, where:

a = Number tattooed at diversion A
y = Number of fish trapped in diversion B
b = Number of tattooed fish recovered at B
x = Total migrants.

Table 6 presents recovery data.

In any analysis of movement on the Imnaha, there are some potential sources of error because one or more of the following assumptions may not be valid:

1. Migrants entering diversion B are representative (a random sample) of all migrants in the river. Wales and Coots (1955) tested a similar hypothesis and found it to be acceptable.

2. Handling and the effects of chloretone are negligible. Live-box tests of marked fish were made. The assumption is regarded as valid.

3. The mortality of marked fish in the river is no different from that of unmarked fish. This is pure assumption and remained so during the project.

Results of the Experiment

Twenty-six days elapsed before tattooed fish from the uppermost screen A first reached screens B and C (the arrival was simultaneous), at distances of 14 and 15 miles, respectively. Three days elapsed before marked fish from screen B reached screen C, a distance of 1 mile. Tattoo marks were discernible as long as 102 days. Marked fish from screen A were recovered at screen C until December 5.

TABLE 6.--Imnaha River marking experiment, 1956

	Screen A (68 days)
Total of chinook trapped	14,435
Number marked (blue) (20%)	2,881
	Screen B (68 days)
Total of chinook trapped	10,358
Marked chinook from A	91
Number of remainder marked (white) (20%)	1,979
	Screen C (127 days)
Total of chinook trapped	8,089
Marked chinook from A	39
Marked chinook from B	21

Marked fish recovered at screens B and C, as recorded in table 6, revealed the occurrence of re-diversion among migrant salmon fingerlings. A calculated total of 3.16 percent of the A fish came through the B diversion, and 1.35 percent were recovered at screen C. Of the B fish that were marked, 1.06 percent were re-diverted at screen C.

The proportions of fish diverted into an irrigation ditch in relation to the total estimated migrants were somewhat similar to those reported by Wales and Coots (1955) in a study which involved the trapping of marked fish in a known fraction of stream flow.

Estimates of total movement past two lower installations were made on the basis of recovery data. Assuming no losses between the screens, it was estimated that 328,000 chinook fingerlings were moving past B within the test period; 599,000 from screen A to screen C; and 763,000 from screen B to screen C.

The proportion of the estimated total populations diverted at screen B was 3.1 percent, whereas 1.3 percent of the moving fish entered diversion C (table 6).

Proportions would probably vary in relation to angle of diversion take-off and the manner in which gravel dams are erected in northeastern Oregon rivers to divert irrigation water.

Summary and Conclusions

More than 200 rotary fish screens have been installed in diversions in northeastern Oregon to bypass salmon and steelhead fingerlings back into streams. Over a 5-year period, screens were sampled continuously to determine their effectiveness in bypassing migrant fishes. Bypass trap catches ranged from 4 to 32,685 migrants per installation, per irrigation season.

Rotary-screen efficiency is directly related to the perfection of side and bottom seals and to the mesh size. Excessive water approach velocity (more than 1.5 feet per second) may contribute to losses through or over screens, especially with fry.

There is evidence that the diversion take-off angle from a stream is significant to the number of migrants entering irrigation ditches. The size of the diversion alone is not sufficient to account for all fish diverted.

Estimates of migrant chinook populations were made on the Imnaha River by marking and a recovery at lower screen bypass traps. The assumption that migrants are re-diverted regularly at two or more screens within a river system was found to be true.

Based on population estimates, more than 3 percent of all the downstream fish in the Imnaha River were diverted into a ditch containing about 4 percent of the flow of the river. The angle of diversion take-off was less than 20°.

Downstream migration peaks among steelhead trout and salmon were recorded in May, June, August, September, and October in 10 streams in northeastern Oregon.

Averaged bypass trap data indicate that a total annual saving could range from 300,000 to more than 1,000,000 salmon and steelhead trout migrants in northeastern Oregon alone.

The field testing of rotary screens points up the importance of careful maintenance and installation immediately after activation of an irrigation ditch. Screens which operated in some diversions after July 1 were found to be of no value because fish migration had ceased. In such areas, screens were removed, serviced, and stored, releasing a maintenance man for other duties.

Acknowledgments

Appreciation is expressed to the northeast region's screen maintenance personnel (Game Commission) for their systematic collection of useful field data and to Dr. Lyle Calvin, Oregon State College, for suggestions regarding presentation of material.

Literature Cited

Chapman, D. W.
1957. An improved portable tattooing device. Prog. Fish-Cult. 19 (4): 182-184.

Duncan, D. B.
1955. Multiple range and multiple F tests. Biometrics 11: 1-42.

Leitritz, Earl
1952. Stopping them: the development of fish screens in California. Calif. Fish and Game 38 (1): 53-62.

Schaefer, M. B.
1951. Estimation of size of animal populations by marking experiments. U. S. D. I., Fish and Wildl. Serv., Fish. Bull. 69 (52): 191-203.

Sumner, F. H.
1953. Migrations of salmonids in Sand Creek, Oregon. Trans.

Sumner, F. H. (continued)
Am. Fish. Soc. 82 (1952): 139-150.

Wales, J. H.
1948. California's fish screen program. Calif. Fish and Game 34 (2): 45-51.

------ E. W. Murphey, and John Handley
1950. Perforated plate fish screens. Calif. Fish and Game 36 (4): 392-403.

------ and Millard Coots
1955. Efficiency of chinook salmon spawning in Fall Creek, California. Trans. Am. Fish. Soc. 84 (1954): 137-149.

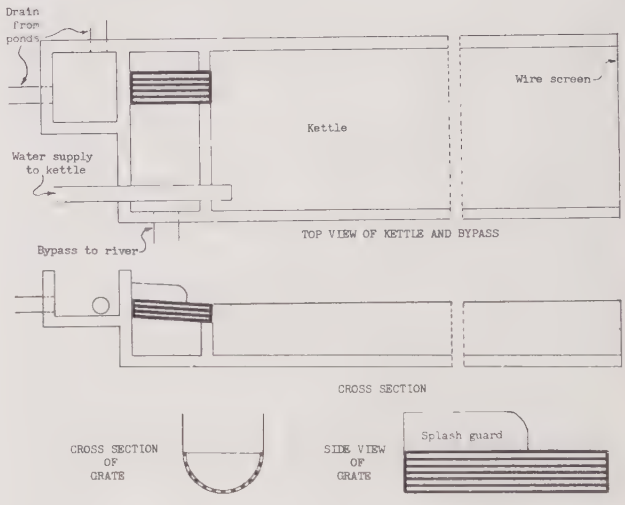
Whalls, M. J., D. S. Shetter, and J. E. Vandett
1957. A simplified rotary fish screen and an automatic water gate. Trans. Am. Fish. Soc. 86 (1956): 371-380.

BYPASS TO ELIMINATE ACCUMULATED WASTE WHEN DRAINING EARTHEN PONDS

Earthen ponds are being used to produce catchable-size trout at many hatcheries in the United States. Economical construction is the main advantage. It is impossible, however, to clean the ponds without draining them and removing the fish. If the ponds are drained into a common kettle, much of the accumulated waste goes in with the fish. This was the problem we faced at the Red River Hatchery.

We have 13 ponds that can be drained into a common kettle. It had been our practice to let the fish remain in these ponds from 3 to 4 months without cleaning; and when a pond was drained into the kettle, a large amount of accumulated waste went in with the fish. This resulted in the loss of a great number of fish from suffocation before the water in the kettle could remove the waste material.

In the summer of 1958 we developed and installed a bypass to eliminate this problem. This bypass, shown in the diagram, is a grate constructed by welding 39 steel rods, each 1/2 inch square, to a semicircular bar, 1-1/2 inches by 3/8 inch. A 1/2-inch space was left between each of the rods. This grate, which has a fall of 3 inches in 5 feet, connects the drain from the ponds with the retaining



wall of the kettle. Under the grate is a separate drain leading to the nearby river. This device enables the fish to slide over into the kettle, while allowing the water and waste to be bypassed.

Owing to the fact that the water in the kettle remains clean, it is now possible to drain a pond with relative safety. Even if the fish do get sick before they reach the kettle, they soon revive in the fresh water.

---DAN REGAN and AL YAPLE, New Mexico Department of Game and Fish, Questa, New Mexico.

THE EFFECT OF CONTROLLED LIGHT ON THE MATURATION OF ADULT BLUEBACK SALMON

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EACH NEW HYDROELECTRIC-POWER DAM CONSTRUCTED ON THE COLUMBIA RIVER increases the hazards to adult salmon ascending the river to spawn and to their progeny returning to the ocean. The complete power development of the Columbia, as now proposed, may in time preclude the use of the upper tributary streams as propagation areas for salmon.

Salmon are now using the upper Columbia tributaries. In order to maintain these stocks in the event that this area becomes unusable, a program of trapping, spawning, and rearing all salmon at lower river locations might be feasible. An operation like this would involve diverting the adult salmon near the beginning of their migration run into holding ponds and retaining the fish until they matured. For long-run species such as spring chinook salmon (Oncorhynchus tshawytscha) and blueback salmon (O. nerka), this holding period would extend for several months.

Mortalities of adult salmon are often severe during a long holding period. Even under the most favorable conditions some fish are lost from disease and general debilitation, often just as they reach maturity. If the retention time could be shortened by inducing the fish to spawn earlier than normal, a greater number of female salmon should reach maturity and thereby increase the egg take.

Experiments have been conducted at the Salmon-Cultural Laboratory to explore two possible methods of accelerating the maturation of adult salmon: by injecting gonadotrophic substances (Burrows et al. 1952, Palmer et al. 1954), and by controlling the amount of light to which the salmon are subjected. The effect of the controlled light will be discussed in this report.

Controlled light has been used successfully to modify the sexual cycle of brook trout (Salvelinus fontinalis). Hatcheries in Rhode Island (Hazard and Eddy 1951) and in New Hampshire (Corson 1955) have used this method to produce brook trout eggs approximately 3 months earlier than the usual spawning time for this species. Salmon, which are closely related to brook trout, were expected to react in a similar manner to controlled light.

Blueback salmon were selected to test the effect of controlled light on maturation. This species is available in adequate numbers for the experiments, has a relatively short spawning period as compared with that of the chinook salmon in this area, and is better adapted than the chinook to holding in the ponds available for the experiments. The results of the experiments with the blueback salmon appear to be applicable to other species of salmon.

Equipment and Procedure

A light-tight cover was installed over a 29- by 130-foot concrete recirculating pond of the Foster-Lucas type. Artificial illumination was provided by fourteen 300-watt incandescent lamps controlled by an

automatic time switch; no outside light was admitted to the pond. An adjacent uncovered pond was used to hold the control fish.

The adult blueback salmon were trapped in the fishway at Rock Island Dam during their upstream migration and transported to the Entiat Station in a fish-distribution truck. Equal numbers of fish were placed in the covered and open ponds, and the time switch which controlled the lights in the covered pond was set to give the desired illumination period.

The ponds were observed daily for dead fish and for signs of color change. Dead fish were autopsied, and probable cause of death and the stage of development of the gonads were recorded. Water-temperature records were maintained for each pond.

The ponds were seined periodically, and the fish were checked for ripeness. After the first ripe females were found, the ponds were seined twice weekly and any females nearing maturity were held in crates. These fish were examined daily, and ripe females were segregated and held overnight before spawning to insure complete ripeness.

All lots of eggs were incubated; and mortalities were recorded during the green-egg, eyed-egg, and fry stages. When the fry reached the swim-up stage, they were placed in troughs and fed. The fingerlings were held at least 4 weeks, when mortalities had dropped to a normal level. The fish were then transferred to the fish-cultural station at Leavenworth, Washington, for rearing.

Results of Experiments

The three experiments will be discussed separately because a different period of light exposure was used each year. The fish which were subjected to controlled light in the covered pond are referred to as the experimental group, and those in the uncovered pond as the control group. The numbers of fish utilized in the experiments, female mortalities, and eggs collected are shown in table 1.

The 1955 Experiment

The experiment began on July 20, 1955, when the fish were put into the ponds. Each of the ponds received 99 fish; however, 2 fish of the experimental group died the first day as a result of handling, leaving 97 in that pond for the experiment.

The original purpose of this experiment was to subject the fish to diminishing amounts of light to accelerate spawning. Instead, because of a malfunction in the timer, these fish were subjected to practically continuous light for a 6-week period. As a result, the experimental group did not begin spawning until 28 days after the first spawntaking in the control group. Almost 90 percent of the females in the control group had spawned before the first eggs were collected from the experimental fish, as indicated in the graph of the spawning times. (See figure.)

Female mortality was higher in the experimental group than in the control group, but the difference was not statistically significant. The potential egg supply (average number of eggs per female times number of females at beginning of experiment) was nearly equal in the two groups; however, 12 percent more eggs were collected from the control group because of greater female survival.

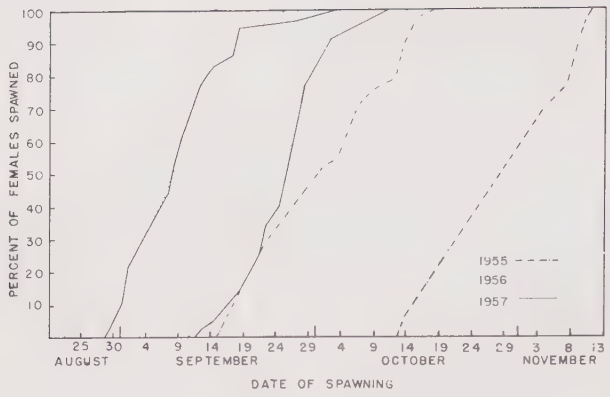
Analysis of variance (Snedecor 1946) of the number of eggs per ounce revealed that the fish from the delayed group produced significantly smaller eggs than the control group. Egg size was apparently not a factor in survival, as the eggs from both groups sustained comparable losses (table 2). Fry mortality was significantly higher in the control lot; however, total mortalities from the egg to fingerling stage were comparable in these lots.

Although the original design of the experiment was not carried out, the experiment demonstrated that the sexual cycle of blueback salmon could be altered by modifying the period of light to which the fish were subjected. If exposure to almost continuous light delayed maturation, then, conversely, a shortened period of "daylight" should accelerate maturation.

TABLE 1.--Numbers of adult blueback salmon used, female mortalities, and eggs taken during the three years

Year:	1955		1956		1957	
Group:	Control	Experimental	Control	Experimental	Control	Experimental
Total number of fish at start	99	97	84	84	82	82
Number of females at start	50	45	39	34	46	54
Total female mortality	6	11	1/ 12	1/ 5	11	18
Number of females spawned	44	34	27	29	35	36
Spawning period	9/15 - 10/18	10/13 - 11/11	9/11 - 10/14	8/23 - 9/25	9/12 - 10/11	8/29 - 10/3
Potential number of eggs	131,600	129,735	115,167	96,458	122,774	148,662
Total number of eggs collected	115,828	98,036	79,725	82,177	93,412	99,106
Percentage of potential eggs	88	76	69	85	76	67
Average number of eggs per female	2,632	2,883	2,953	2,837	2,669	2,753
Average number of eggs per ounce	1/ 283	1/ 325	293	298	298	301

1/ Significant difference at the 5% confidence level.



Comparisons of the effects of varying periods of light exposure on the spawning time of blueback salmon. Spawning of the control groups began between September 11 and September 15 during the 3 years.

The 1956 Experiment

On July 18, 1956, 168 adult blueback salmon were transported from Rock Island Dam and 84 were placed in each of the 2 ponds. The time switch controlling the lights in the covered pond was set to allow 9.25 hours of artificial light daily, or approximately 5 hours per day less than the normal. This period of illumination was comparable to that of normal daylight occurring on October 1, the midpoint of the spawning period of blueback salmon in this area.

Spawntaking began in the experimental group on August 23, after 36 days of exposure to reduced light. Spawning activity increased until September 1, when there was a noticeable decrease (see figure). On September 6, the period of light was reduced to 6 hours per day. A marked increase in the rate of female maturation followed this reduction of the light. Egg collection began in the control group on September 11, 19 days after the first spawntaking in the experimental group.

Female mortality was significantly less in the experimental group than in the control group; therefore, a higher percentage of the potential egg supply was collected. The difference in average egg size of the two groups was slight, and all appeared normal; however, green-egg mortality was almost four times higher in the eggs from the accelerated group than in the eggs from the control group. Eyed-egg and fry losses were comparable, but fingerling mortality during the first-feeding stage was significantly higher in the accelerated lot.

The 1957 Experiment

Because an exposure to more than 23.5 hours of light per day delayed spawning for 4 weeks in 1955, it appeared probable that a very short period of light would advance spawning more than the 9.25-hour exposure in 1956. The ponds were stocked with 82 fish each on July 18, 1957, and the time switch controlling the lights in the covered pond was set to allow only 1 hour of illumination per day.

On August 27, several nearly mature females in the experimental group were segregated. The first female was spawned on August 29, 41 days after the beginning of the experiment; and spawning was completed on October 3. Collection of eggs in the control group was begun on September 12, 14 days after the first spawning in the experimental group, and was completed on October 11.

Although spawning was advanced 14 days in the experimental group of fish, female losses were higher in this lot than in the control group. This difference in mortality, however, was not statistically significant. The number of eggs taken, in comparison to the potential egg supply, was lower in the experimental group, from which 67 percent were collected; from the control group, 76 percent were collected.

Analysis of the mortalities occurring during the incubation period revealed a significantly higher green-egg loss from the accelerated group as compared to the control group. No significant differences in mortality occurred in the eyed-egg, fry, and fingerling stages.

Discussion

These experiments demonstrated that the sexual cycle of blueback salmon, like that of brook trout, could be modified by

TABLE 2.--Egg, fry, and fingerling mortalities during the three years

Year:	1955		1956		1957	
Group:	Control	Experimental	Control	Experimental	Control	Experimental
Total number of eggs taken	115,828	98,036	79,725	82,177	93,412	99,106
Green egg mortality	3,861	4,010	3,032	10,271	4,072	11,621
Percentage of green-egg mortality	3.30	4.10	[1]3.81	[1]12.48	[1]4.36	[1]11.73
Eyed-egg mortality	923	666	748	766	939	1,048
Percentage of eyed-egg mortality	0.82	0.68	0.97	0.94	1.01	1.01
Fry mortality (to feeding)	3,691	257	126	254	2,172	1,381
Percentage of fry mortality	[2]3.32	[2]0.28	0.16	0.31	2.33	1.39
Total mortality to feeding	8,475	4,933	3,906	11,291	7,183	14,050
Percentage of total mortality to feeding	7.89	5.03	[1]4.90	[1]13.72	7.69	14.18
Fingerling mortality	10,768	2,815	2,892	6,512	1,945	3,010
Percentage of fingerling mortality	9.81	3.02	[1]3.81	[1]9.19	2.26	3.63

[1]Significant difference at the 1% confidence level.
[2]Significant difference at the 5% confidence level.

controlling the light to which the fish were subjected. The effect was not so pronounced in the experiments with salmon as in those reported with trout, owing, in part at least, to the shorter period of controlled light in the salmon experiments. The technique of Hoover (1938) and other workers experimenting with brook trout involved a schedule of modified light used for a period of at least 6 months. In the 1956 experiment at the Salmon-Cultural Laboratory, the salmon were subjected to reduced light only 36 days before the first eggs were collected.

In the 1956 experiment, adult female survival was significantly higher in the accelerated group than in the control. In 1957, the control group had a higher survival than the experimental group, but the difference was not statistically significant. The small numbers of fish used in these experiments make it impossible to predict the increase in female survival to be expected from an acceleration in maturation where a longer holding period would be used. There is every reason to expect, however, that a significant reduction in holding mortality would result.

The cause of the higher mortalities in the eggs from the early spawning salmon is not known. Hazard and Eddy (1951) reported greater fertility from early spawned brook trout eggs than from those collected at the normal time. Corson (1955) reported losses higher than usual from two lots of early spawned brook trout eggs but normal mortality from other lots. The different stocks of trout may account for this variation in egg fertility. The low fertility of the early spawned salmon eggs may have been caused by a too rapid rate of acceleration. If a longer period of light control was available, a more gradual reduction in the light period might reduce the mortality in early spawned eggs. Actually, the green-egg mortality did not exceed 13 percent and cannot be considered excessive.

Both light and water temperature affect the rate of maturation of blueback salmon. Of the two, light appears to be the dominant factor. The water temperatures before and during spawning for the three experiments are shown in table 3. The 1955 experiment, where spawning was retarded, demonstrates most conclusively the dominance of light over temperature. In the two accelerated experiments, 1956 and 1957, the experimental groups of fish spawned during a period of water temperature higher than that of the controls, but the prespawning average water temperature was the same within each experiment. Actually, the water temperatures were higher in the control ponds than in the experimental ponds during the prespawning period of the accelerated groups by approximately 1° F. in 1956 and 2° F. in 1957. The control pond had a temperature as much as 2.5° F. higher than that of the covered pond during the hot, bright days of August in all 3 years of the experiments. Despite these temperature differentials, spawning could be either accelerated or retarded by controlling the length of the light exposure. Temperature, therefore, must be regarded as secondary to light in accelerating sexual maturation.

The extremely short light exposure in the 1957 experiment did not hasten

TABLE 3.--Average water temperatures before and during the spawning periods for the three experiments

Year	Group	Temperature in degrees Fahrenheit			
		Prespawning period	First spawning	Spawning period	Final spawning
1955	Control-----	57	52	50	48
	Experimental	54	47	45	38
1956	Control-----	56	56	53	50
	Experimental	56	58	55	53
1957	Control-----	57	55	53	51
	Experimental	57	55	55	50

maturation, as compared to that of the longer light exposure in the 1956 trial. In these experiments there are indications that a gradually diminishing period of light might provide a greater stimulant to maturation than the abrupt-change technique employed here.

The use of reduced light exposure to accelerate maturation in salmon during a prolonged holding period appears to be entirely practicable and one possible solution to the holding problem. At Entiat the holding period before normal spawning amounted to 2 months. Under different conditions where the holding period would amount to 3 to 5 months, the rate of sexual maturation could be accelerated even more. There is every reason to believe that a normal holding period of 4 months could be shortened by 1 month to 6 weeks. Such a reduction would undoubtedly result in an increase in the survival of the adult fish, which would more than compensate for the increased green-egg losses indicated as being probable in these experiments.

Summary

The results of the 3-year study to determine the effect of controlled light on the sexual maturation of adult blueback salmon may be summarized as follows:

1. Spawning of salmon was delayed in one experiment by lengthening the daily light exposure and was advanced in two experiments by shortening the daily light exposure.

2. Acceleration in maturation appeared to favor higher adult female survival.

3. Green-egg mortalities were significantly higher in the eggs from the accelerated groups.

4. Light, not the water temperature, appeared to be the dominant factor affecting the rate of sexual maturation of blueback salmon.

5. The experiments indicate that use of reduced light to accelerate maturation in salmon is a practical method of reducing adult salmon mortalities during a lengthy holding period.

Literature Cited

Burrows, R. E., D. D. Palmer, and H. W. Newman
1952. Effects of injected pituitary material upon the spawning of blueback salmon. Prog. Fish-Cult. 14 (3): 113-116.

Corson, B. W.
1955. Four years' progress in the use of artificially controlled light to induce early spawning of brook trout. Prog. Fish-Cult. 17 (3): 99-102.

Hazard, T. P., and R. E. Eddy
1951. Modification of the sexual cycle in brook trout (Salvelinus fontinalis) by control of light. Trans. Amer. Fish. Soc. 80 (1950): 158-162.

Hoover, E. E.
1938. Experimental modification of the normal sexual cycle of trout. Sci. 86 (2236): 425-426. (Reviewed, Prog. Fish-Cult. 36:34).

Palmer, D. D., R. E. Burrows, O. H. Robertson, and H. W. Newman
1954. Further studies on the reactions of adult blueback salmon to injected salmon and mammalian gonadotrophins. Prog. Fish-Cult. 16 (3): 99-107.

Snedecor, G. W.
1946. Statistical methods. 4th ed., xvi, 485 pp. Iowa State Coll. Press, Ames.

Erratum: Figure 3 on page 28 of the January 1959 issue was printed upside down.

RECLAMATION OF LAKE HAMILTON, ARKANSAS

Andrew H. Hulsey, Arkansas Game and Fish Commission, Lonoke, Arkansas
and
James Stevenson, Little Rock University, Little Rock, Arkansas

LAKE HAMILTON is one of a series of three lakes on the Ouachita River near Hot Springs, Arkansas. This is a scenic, 7,200-acre lake with a well-developed shoreline and has been a popular recreational area since its construction in 1931. It was built by the Arkansas Power and Light Company primarily as a hydroelectric reservoir; but a land-development program encouraged the sale of lots and the construction of cottages, homes, tourist courts, and other recreational facilities. Today the shoreline of Lake Hamilton is one of the best developed in the State, and the fishing on this lake, as well as on the other lakes of this area, is an important asset to the economy of the resort city.

In 1955 the Arkansas Game and Fish Commission inaugurated a Federal Aid (Dingell-Johnson) Investigation Project F-5-R, which was a 3-year comparative fishery study of Lake Catherine, Lake Hamilton, and Lake Ouachita--all on the Ouachita River and within 20 miles of Hot Springs. It was hoped that the study would provide more information on large reservoirs and lead to management proposals that might be initiated to improve fishing.

One finding of this survey was the existence of an overpopulation of gizzard shad (Dorosoma cepedianum) and drum (Aplodinotus grunniens) in Lake Hamilton. Sampling in the past 3 years revealed an average standing population of 157 pounds of fish per acre, 50 percent of this population being gizzard shad and 21 percent drum. Gizzard shad were the dominant fish. The predator species--such as the largemouth bass (Micropterus salmoides), spotted bass (M. punctulatus), smallmouth bass (M. dolomieu), white bass (Roccus chrysops), black crappie (Pomoxis nigromaculatus), and white crappie (P. annularis)--were no longer able to hold them in check.

The Hot Springs Chamber of Commerce, civic clubs, and property owners on Lake Hamilton were actively interested in this study. They were periodically informed about findings, and frequently they accompanied the survey crews on various phases of the work. At the conclusion of the project, these groups desired that management recommendations be followed.

As the Arkansas Power and Light Company had planned for some months to lower the water level in Lake Hamilton by 10 feet in October 1957 to permit property owners to do dredging and construction work, this appeared to be the ideal time for conducting the recommended shad-control measure on this lake. Consequently, the Hot Springs Chamber of Commerce requested the Arkansas Game and Fish Commission to conduct a shad kill on Lake Hamilton and pledged its full cooperation and support. A campaign was conducted to raise money to help defray the cost of the rotenone. The Game and Fish Commission agreed to provide the technical advice, apply the rotenone, and share the expense. The Chamber of Commerce and other groups in the Hot Springs area were to assume responsibility for disposal of the unwanted fish.

The water level was lowered at the rate of 6 inches a day beginning the first of

Loading a barrel of rotenone on a special rack in a 14-foot flat-bottom boat.

Many of the dying shad struggled at the surface before sinking.

In the cold tailwater below Blakely Mountain Dam, many drum were killed.

September. By September 20, the lake level was 10 feet below normal pool elevation. At this reduced level, the lake contained about 6,000 surface acres of water. A fishery biologist was detailed to mark off desirable areas and determine the water volume. Approximately half of the area of the lake was selected and divided into 7 segments. Maps identifying these segments and showing the depths, water volume, and approximate quantity of rotenone (Pro-Noxfish) needed, were made.

On October 30, final preparations were made with the assistance of the fishery personnel and local game wardens. Three loading stations were set up, and the calculated quantity of chemical (plus an emergency supply) was sent to the respective stations. Eight boats were provided with a fitted stand that had a low center of gravity to carry a 55-gallon drum of the rotenone preparation. Each boat operator was given a map showing the area, depth, and volume of water in an assigned section of the lake and the calculated amount of chemical needed for treatment. Each man was responsible for applying the chemical to his area in such a way as to obtain maximum even distribution until a concentration of 0.10 p.p.m. of this rotenone was built up throughout the lake.

The effect of treating about 4 miles of the headwater of the lake, immediately below Blakely Mountain Dam, was questionable because of the cold, swift water and apparent absence of shad. The Arkansas Power and Light Company and the Corps of Engineers were requested to reduce the power generation from Blakely Mountain Dam in order to reduce the volume of flow and prevent dilution of the treated water beyond the effective concentration. These groups promptly agreed to aid the operation by splitting the generating load among all three dams. It was decided to treat this upper region as originally planned.

On October 31, actual operations were begun. The chemical was applied directly to the water by gravity feed through a rubber hose from the mounted drum. The propeller of the outboard motor mixed the small stream of this undiluted rotenone preparation with the water. It required about 8 hours to treat the areas designated. After the first 5 hours, application was speeded up by using larger (garden) hose.

Approximately 3 hours after application was started, 4- to 6-inch young-of-the-year gizzard shad showed signs of distress. Concentrated schools of these fish were observed dying, but little evidence of affected adult shad could be seen. In a little over 4 hours, large numbers of drum were seen surfacing in the upstream area below Blakely Mountain Dam. After the 0.10-p.p.m. concentration of the rotenone was obtained (6 or 7 hours after the start of the treatment) and observations indicated that few adult shad and drum were surfacing in the lower region of the lake, it was decided to increase the concentration to 0.13 p.p.m. --and in some areas to 0.15 p.p.m. The use of more rotenone in the lower regions of the lake assured the killing of adult shad--and possibly drum. Twenty-two hundred and fifty-five gallons of the rotenone was applied to approximately 3,000 surface acres of water.

On November 1, all working crews surveyed and observed their areas. Many fish were floating and lying on or near the shoreline. The stronger concentrations killed a few thousand pounds of buffalo, and the crews recovered fish ranging in size from 25 to 85 pounds, along with such game species as bluegill (Lepomis macrochirus), redear (L. microlophus) and longear sunfish (L. megalotis), warmouth (Chaenobryttus coronarius), black and white crappie, and spotted, largemouth, and white bass. The white bass appeared to be more susceptible than other sport species. All sizes of shad and drum were observed lying along the banks and dying in the open water. It appeared that the desired effect had been obtained in the treated areas, and that the initial kill was about over. The water, however, was still toxic.

The Arkansas Power and Light Company was then asked to dewater Lake Hamilton about 1 foot. This was done during the next 18 hours, and the use of the chemical was considerably enhanced. The treated water in the bays and upper

reaches of the lake was pulled down and into the untreated areas with remarkable results. Shad and drum immediately began to suffer in untreated areas. Some drum were dying in the main channel as far as 2 miles below the original area treated. Observations on November 3 (4 days after the operation began) showed that the water over most areas of the lake was still toxic to young gizzard shad, and it was believed that at least a 90-percent shad kill was obtained for the entire lake.

The water in some of the treated areas appeared to remain toxic for about a week. Reports after the fifth day revealed that local fishermen were making a few catches of largemouth bass and crappie. Thereafter, fishing success picked up, the crappie fishing being better than usually experienced at this time of year.

It was difficult to calculate accurately the numbers and weights of fish killed. Probably 60 percent of the fish affected never floated but sank to the bottom. During the time of treatment and for 3 or 4 days afterward, hundreds of boats with spectators using dip nets undoubtedly collected many fish and took them home. The Chamber of Commerce had set up 15 disposal stations on the lake and publicized these in the local newspapers and on radio so that volunteers could aid in collections. Because of the small percentage of fish that floated and the fact that most property owners disposed of fish adjoining their property, comparatively few fish were brought to the collecting stations.

A large number of drum, but few shad, were killed in the upper reaches of the lake. Comparatively few dead game fish were observed in this area. In the lower part of the lake, gizzard shad formed the bulk of the kill and drum and buffalo were next in order by weight. In the neck of one of the two larger creeks, a fairly heavy kill of game fish, along with rough fish, was obtained. This was due to a stronger application in the narrow, more shallow, channel of the creek than had been anticipated. In one of the larger shallow basins, a number of game fish were also observed on the bottom and along the shoreline. This was the area where large buffalo were found and had purposely been treated with the chemical at a concentration of 0.15 p.p.m.

On the day before treatment, 100 baskets (4 feet square, made with 0.25-inch mesh hardware cloth) were submerged on the bottom in different parts of the lake and marked with floats. It was hoped that fish might settle on these baskets and provide an estimate of the kill. The baskets were raised the next day. Although a few contained a small number of young sunfish, many were empty. Several could not be found because motorboats had severed the float line. It was learned that many had been raised--and perhaps emptied--by people cruising the lake. This attempt to get a count was unsuccessful.

Shoreline counts were made in an attempt to ascertain the percentage of game fish killed. Each biologist estimated the number of fish killed in his area. From observations by those associated with the project, it appeared that at least 90 percent of the gizzard shad and possibly 50 percent of the drum population were killed. Shoreline counts indicated that about 1 percent by weight of the total kill was game fish (including the various sunfishes, as well as bass and crappie).

Because of the inability to obtain satisfactory counts of total fish killed in an area, it was decided to use the data previously obtained from the 3-year population studies. From these data the gizzard shad population in Lake Hamilton was calculated to weigh 565,200 pounds, and that of the drum to weigh 237,400 pounds. As it had previously been estimated that 90 percent of the shad and 50 percent of the drum populations were killed, this operation was believed to have removed 508,700 pounds of gizzard shad and 118,700 pounds of drum. Shoreline counts indicated that 1 percent, or about 6,500 pounds, of game fish was killed. Apparently, uncounted thousands of madtoms, darters, logperch, brook-silverside minnows, and other species were also eliminated. Total weight of these species was, of course, small; but their reduction is considered very important from the biologist's standpoint. Admitting that no reliable method was

available for accurate calculation of the kill (objective calculations based on bank samples, etc., gave very high poundage), and that the foregoing figures are arbitrary, removal of approximately 650,000 pounds of fish with 2,255 gallons of Pro-Noxfish does not seem unreasonable.

Evaluation at this early date must be confined to the fish-kill operation itself. The mechanics of the operation were highly satisfactory. Credit is given to detailed planning, efficient execution of work assigned to personnel, and cooperation from local groups. Workers who participated in the project subscribe to the views expressed in a front-page article of the Hot Springs Sentinel-Record, "Lake Hamilton Rough Fish Kill Called Huge Success." Sound judgment concerning the permanent value of the project must await the results of follow-up studies and, in a more practical vein, the future success of fishermen.

SUNBURN IN FINGERLING RAINBOW TROUT

Most of the rainbow trout fingerlings of the U. S. Fish-Cultural (Leetown) Station at Kearneysville, West Virginia, had been moved from the black-asphaltum-painted troughs in the hatchery to circular pools outdoors early in April 1957; but several thousand were not moved until May 31. That day and the next 2 days were cloudless, with very bright sunlight and low humidity. Within 2 days some fish began to lose equilibrium, darkened, and developed necrotic areas behind the head and around the dorsal fin. There was a temporary increase in mortality in the pools.

Three tests were made to learn whether exposure to ultraviolet rays would produce the symptoms just described. The controls were normal fish which had been moved outdoors earlier in the spring. The test fish were taken from those that had been returned to the hatchery and had fully recovered from the apparent sunburn.

In the first test, 20 fish held in 1 inch of flowing water were exposed to a sunlamp (275 watts) at a distance of 18 inches for 36 hours. This did not visibly affect the fish. After 12 hours' exposure to the light at a distance of 12 inches, however, the fish were darker than the controls and had white necrotic patches identical to those seen on the fish that had developed the apparent sunburn in the pools.

In the second test, 20 fish held in 2 inches of water were exposed to the same sunlamp at a distance of 24 inches for 6- to 7-hour intervals for 3 successive days. On the last day the distance was reduced to 12 inches. The fish showed no distress.

In the third test, 20 fish in 2 inches of water were exposed to a germicidal lamp (15 watts) for 9 hours at a distance of 12 inches. Soon after the test began, the fish began showing distress. They crowded along the sides of the trough, trying to avoid the direct rays of light. After 6 to 7 hours' exposure, white patches appeared on the dorsal areas. The next morning 2 fish were dead. In 48 hours 6 more fish had died. The remaining fish were very much in distress, with necrotic dorsal areas, and in 3 days were darker than the controls. Three more fish died during this 3-day period.

The fish in the first and third tests, like the fish that had darkened and developed dorsal necrosis when moved from the hatchery troughs to the outdoor pools, were rough to the touch. This showed that prolonged exposure to artificial ultraviolet rays had damaged the mucous cells.

Macroscopic and histological examination of fish that had become sunburned in the pools, and of fish exposed to artificial ultraviolet light, showed that the resultant lesions were identical.

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NOTES ON THE PROPAGATION OF THE FLATHEAD CATFISH, *PILODICTIS OLIVARIS* (RAFINESQUE)

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CONSIDERABLE INTEREST IN THE PRODUCTION OF FISH FOR FOOD AS WELL AS SPORT has been shown in recent years. As a result of this interest, a new look is being taken at several fish species which, although quite well known, have never been utilized to the extent that artificial propagation of the fish seemed necessary or desirable.

Among such species can be listed the flathead catfish, Pilodictis olivaris (Raf.). Long a popular commercial species in the Mississippi River drainage and elsewhere, in recent years the flathead catfish has received notice as a possible pondfish for culture in artificial impoundments.

From experiments at the Alabama Experiment Station, Swingle (1954) found that in ponds the flathead catfish grew at a rate of 2 pounds per year, had an excellent flavor, and appeared promising as a commercial species. He stated that the greatest disadvantage of the species appeared to be the difficulty of obtaining young fish for stocking, as the flathead did not spawn naturally in ponds. However, the species has been known to spawn in captivity. Fontaine (1944) observed the successful spawning of flathead catfish in the Dallas Aquarium. He stated that their spawning behavior was similar, in some degree, to that of the channel catfish. Toole (1951) stated that some hatcheries in Texas had attempted to propagate the flathead catfish, but that their efforts were rarely successful.

Johnson[1/] used several techniques in an unsuccessful attempt to obtain reproduction of flathead catfish in captivity. His efforts included holding the fish in pools with a strong current and the use of hormone injections.

A few wild brood fish were obtained in 1953 by the U. S. Fish-Cultural Station at Marion, Alabama, for use in an attempt to propagate the species and provide a supply of small fish for experiments on commercial production of the flathead.

The pen method, similar to that used in channel catfish culture (Toole 1951), was used with no success for 3 years. By the spring of 1956, the brood stock had dwindled from the original 11 fish to 4. These 4 appeared to be 2 males and 2 females.

On April 3, 1956, the fish were paired according to sex and size as well as possible and placed in two spawning pens on the Marion Station. One pair of brood fish weighed 17 pounds; the male was about 1.5 pounds heavier than the female. The second pair weighed 16 pounds, and the fish were about the same size.

The fish were observed at intervals after being placed in the spawning pens. On May 1 the spawning container, a rectangular wooden box open at one end

[1/]Johnson, M. C. Some experiments in the propagation of the flathead catfish, Pilodictis olivaris (Raf.) in ponds. M.S. thesis. Alabama Polytechnic Institute, Auburn, 1950.

(figure 1), was clean and one of the brood fish was inside. When the container was checked on May 7, an egg mass was felt. The water temperature at this time was 77° F. There was no internal pulsation of the egg mass, and it was assumed that the eggs had been deposited recently.

The egg mass was removed for an attempt at artificial incubation. Weight of the egg mass was slightly less than 2.4 pounds. There was no attempt to enumerate a sample of the spawn, but it was estimated that the mass contained about 15,000 eggs. An open hatching jar was used as a hatching container. The attempt was a failure, due apparently to a combination of factors including low temperature, excessive iron in the water supply, and an unsuitable incubation device. Only 60 fry hatched, and all but 1 of these were lost during efforts to feed them in water at a temperature of 70° F.

After this first spawn had been obtained, the other female flathead catfish was placed in the pen with the successful male. On May 19 eggs that appeared to be about 48 hours old were noted. Because of the previous experience with a hatching jar, the eggs were left in the spawning container. The female was not removed, and the area appeared to be quiet and free from disturbance during the incubation period. According to Murphree's (1940) development chart on channel catfish eggs, the fry should have hatched by May 24. At that time the pen was visited and the container was raised. Only a few fry were found; the remainder apparently had fallen prey to the brood fish or some other animal.

A few additional flathead catfish were collected for brood stock in the fall of 1956 and early in the winter of 1957. These fish, with the four acclimated flatheads, were divided into two lots at spawning time: one lot was paired and stocked in spawning pens, and the other was placed in a 0.4-acre spawning pond. The pond was equipped with spawning boxes and 10-gallon milk cans that were located on all sides of the pond. The pens were stocked on April 30; the pond was stocked on May 4.

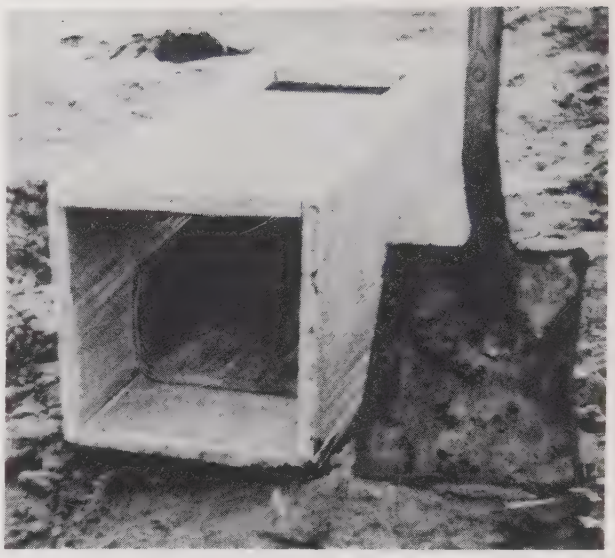


FIGURE 1.-- Container similar to that used for spawning of flathead catfish. The opening (6 inches square) on the top of the box is kept covered except during inspection. Within the container is a liner of roll roofing to facilitate the removal of eggs.

The fish collected in the fall of the previous year seemed to be in spawning condition, but those taken from another stream in midwinter were thin and unpromising in appearance. One of the acclimated females that had spawned the previous year was placed in the pond, and the other was paired with an acclimated male in a spawning pen. This pair of fish weighed 17.6 pounds; the male was slightly larger than the female.

On May 13 eggs were felt in the pen stocked with acclimated fish. The appearance of a sample indicated that they had been deposited the previous day. Water temperature was about 75° F. at the time of spawning. The eggs were undisturbed except for a small sample carried to the laboratory for observation.

The sample of flathead catfish eggs was placed in a petri dish filled with tap water. They were then observed each day with a binocular dissecting microscope, and notes were taken on the rate of development. The table is a chronological record of the daily observations. The stages of development appear to be

THE DEVELOPMENT OF FLATHEAD CATFISH EGGS

Date (1957)	Development	Incubating temperature (°F.)	Age (days)
5/12	Presumably spawned.	[1]/ 75.2	0
5/13	No internal pulsation. Egg cream-colored, with darker prominent yolk; about 5 mm. in diameter.	[2]/ 77.5	1
5/14	Internal pulsation visible.	76.5	2
5/15	More vigorous movement. Tip of tail touches head. Vertebral column distinct; brain area visible as a darker expansion of spinal column. Circulatory system developing over yolk mass.	76.0	3
5/16	Embryo turning more vigorously, 90° to 180° each movement. Circulatory system visible to naked eye. Yolk mass reduced in size. Eyespot visible to naked eye.	76.5	4
5/17	Movement of embryo active. Dorsal aorta visible. Noticeable heart beat. Barbels and eyespot prominent. Yolk mass decreasing.	78.5	5
5/18	Movement active. Network of blood vessels on yolk increasing. Head structure more prominent.	77.5	6
5/19	Embryo moving freely within shell. Opercular movement visible. Entire body taking on reddish color. Yolk size decreasing.	76.0	7
5/20	Fry hatched, actively moving about dish. Total length, about 11 mm.	76.5	8
5/21	Body of fry gray and turning darker. Moving about energetically.	80.5	9
5/22	Head of fry almost black. Yolk sac still prominent. Movement active and continuous for extended periods.	80.5	10
5/23	Body of fish continuing to take on darker color. Total length, 15 mm.	78.0	11
5/24	Yolk sac still present but greatly reduced in size. The color of fry grayish black. Movements active and continuous for extended periods.	78.0	12

[1]/ Water temperatures taken by recording thermometer with bulb set at same depth as the spawning containers.

[2]/ Mean air temperatures obtained by averaging maximum and minimum air temperatures reported by the nearest Weather Bureau station. Room temperatures taken at 9:30 a.m. daily averaged 2.4° higher than these means. Water in the shallow dish where these eggs were incubated probably approximated these temperature means.

generally similar to those reported by Murphree (1940) for the channel catfish.

On May 23 the spawning pen was visited and the fry were transferred to the holding house. A count of the fry recovered placed the number hatched and collected at 9,947. At this time they were dark gray, about 0.5 inch in length, and still carried a noticeable yolk sac, although they were quite vigorous in movement. Figure 2 illustrates the size and appearance of the newly hatched fry with three unhatched eggs.

After they had been counted, the fry were placed in a wooden rearing trough supplied with pond water. Beef liver finely ground in a food blender was offered to the fish about six times daily. In addition, small amounts of dry meal (mixed according to the Cortland No. 6 formula) were sprinkled over the surface of the water in the trough.

Though it was difficult to tell surely, the fry appeared to be consuming some of the food. On May 28 mortality increased from an average of 8 fish daily to 130 and an examination of the fish showed the presence of a heavy infestation of Trichodina sp. A 45-minute treatment with formalin at a rate of 1:4,000 was administered after identification of the parasite. This treatment effectively removed all signs of the parasite from the body surface of specimens observed. Mortality continued to be high after treatment, and more than 1,000 dead fish were removed from the trough on May 31. Cause of the continued mortality has not been ascertained, but apparently the fry were not feeding satisfactorily and the non-feeders were dying from starvation.

The fry were transferred to screen boxes (2 feet square and 2 feet deep) and placed in the shallows of a well-fertilized pond. The fish were fed lightly with meal after this move. Mortality continued to be heavy for several days.

On June 14 the boxes were raised and 607 fish weighing 311 grams were removed. Total length of the fingerlings ranged from about 21 millimeters to 35 millimeters. At this time the characteristic body and head of the flathead catfish were very recognizable and the color of the fingerlings was almost black.

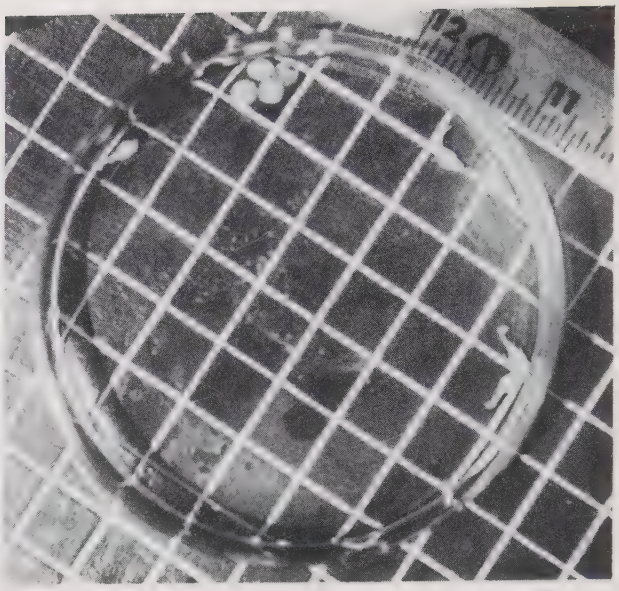


FIGURE 2.--Developing flathead catfish eggs and newly hatched fry. Three eggs are at the top of the dish; fry are visible at the right and at the upper left.

No further spawning was observed among the wild brood fish, either in the spawning pond or in the pens. Several of the penned male fish gave signs of readiness to spawn, keeping the container clean and driving the female about the pen. Several female fish, including one of the spawned females, were lost because of damage to the caudal peduncle--damage probably inflicted by the male during efforts to drive the female into the spawning container. This may be a disadvantage of the pen method.

After being stocked with flathead catfish, the spawning pond was invaded by green sunfish; so after the spawning containers had been checked for a month with no results, the pond was drained and the best of the brood fish were moved to the pens for use in an experiment with pituitary injections.

About a month after the eggs were obtained, the five best females were given pituitary injections in accordance with a method outlined by Clemens and Sneed (1957). Channel catfish pituitary material

treated with dry acetone was used at a rate of about 1 milligram per pound of live weight. An injection was made intraperitoneally each day for 3 days. The females were then replaced in the spawning pens with male fish. There was no spawning activity during 4 days after this treatment, so a second series of injections was given. Channel catfish pituitary material was used at the previous rate for the first injection; material from the speckled bullhead, Ameiurus nebulosus marmoratus (Holbrook), was used for the second, third, and fourth injections. After the fourth injection each female was again paired with a male in the spawning pens. Aside from a slight, noticeable reddening of the vent area of the injected fish, no reaction was obtained.

Evaluation of the experience gained in attempting to propagate the flathead catfish provides a basis for the following suggestions which may be useful for guidance in future propagation work with this species.

1. The development of a healthy, well-fed, acclimated or domesticated stock of brood fish seems to be essential. In 1956, when both female fish spawned at Marion, the fish had been in captivity for 3 years. They had been held since the previous spring in a 0.4-acre pond stocked with fathead minnows at a rate of 287.5 pounds per acre. This food was supplemented with 90 pounds of Gambusia per acre. As the total weight of the 4 flatheads was 23.5 pounds, there was 6.4 pounds of forage fish for each pound of catfish.

2. The pen method of channel catfish culture may be used to obtain spawn if close observation can be maintained to assure compatibility of males and females. The same indicators denoting spawning readiness in channel catfish appear valid for the flathead.

3. Spawn should be removed to a hatching trough if dependable incubation equipment such as that described by Morris (1939) is in operation. Otherwise, eggs should be allowed to hatch in the pen without disturbing the brood fish.

4. The fry should be moved to a well-fertilized rearing pond, as in the method described by Crawford (1958) for use in rearing channel catfish.

5. The young flathead catfish develop like channel catfish of the same age except that small flathead fingerlings grow more rapidly. The growth rate of the young observed was good, as 3-week-old fish numbered 885 per pound. If this rate continued, a size suitable for distribution (3 to 4 inches) could be obtained in 50 to 60 days.

6. Some feeding experiments will be needed before extensive propagation of the species can be accomplished. The fry did not take artificial food in troughs as well as channel catfish. In ponds, the brood fish would not eat cut fresh fish or the commercial fish food offered. They did show a 60-percent increase in weight during a season in a pond which had been stocked with fathead minnows and Gambusia at a rate of 380 pounds per acre.

Literature Cited

Clemens, H. P., and K. E. Sneed
1957. The spawning behavior of the channel catfish, Ictalurus punctatus. U. S. D. I., Spec. Sci. Rept. Fish. 219. 11 pp.

Crawford, Bruce
1958. Propagation of channel catfish (Ictalurus lacustris) at State fish hatchery. Proc. Southeast. Asso. Game and Fish Comm. 1957: 132-141.

Fontaine, P. A.
1944. Notes on the spawning of the shovelhead catfish, Pilodictis olivaris (Rafinesque). Copeia 1944 (1): 50-51.

Morris, A. G.
1939. Propagation of channel catfish. Prog. Fish-Cult. 44: 23-27.

Murphree, J. M.
1940. Channel catfish propagation. T. J. Rennick (private printing). 24 pp.

Swingle, H. S.
1954. Experiments on commercial fish production in ponds. Proc. Southeast. Asso. Game and Fish Comm. 1954: 69-74.

Toole, Marion
1951. Channel catfish culture in Texas. Prog. Fish-Cult. 13 (1): 3-10.

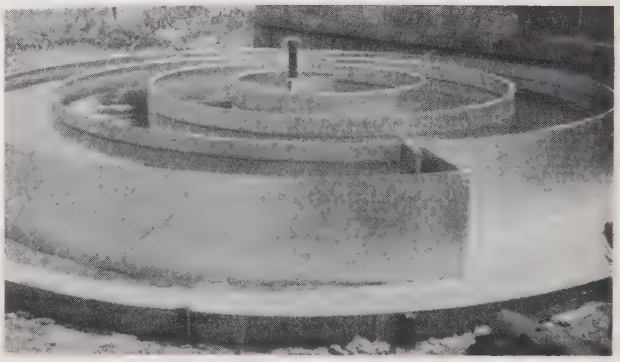
AN INEXPENSIVE EXPERIMENTAL SPIRAL RACEWAY

The spiral raceway has been studied in connection with channel catfish culture at the U. S. Fish-Cultural Station at Tishomingo, Oklahoma. As this is essentially one wall of a standard linear raceway curved to form a spiral, there is a substantial saving in construction materials. Being compact, the spiral takes less space than the conventional raceway of similar length. Also, because the drainage fall can be built into the spiral raceway, need for a gradually sloped area is eliminated.

The finished spiral raceway is 108 feet long, 22 inches wide, and occupies a space about 13.5 feet in diameter. The wall is made of 22-gauge galvanized sheet metal, 20 inches high and 108 feet long. The rim, made of 0.5-inch galvanized pipe and couplings, is attached to the top edge of the wall by 0.25-inch bolts.

To get the proper curvature in the pipe that forms the top rim: (1) Determine the width of raceway desired and divide by 3.14. This figure will be the diameter of a circle whose circumference equals the width of the raceway. (2) To a round pole cut to this diameter, attach a long string or very flexible wire. (3) Attach a marker to the other end of the string and scribe a spiral line on concrete or smooth ground. As the string is wound about the pole, a spiraling line can be properly spaced to the predetermined width of the raceway. (4) Fit the pipe to this line with pipe benders. The metal for the wall should be put through a roller to obtain some curvature, though exactness is not necessary.

After installing a water-supply line to the center of the proposed raceway area, grade the area and form a base of approximately the shape and fall planned for the



final concrete foundation. This can be done by putting the spiraled pipe in position and adding sand, gravel, or cinders to make the floor slope gradually from the center to the drain. About 5 or 6 inches of fall is enough for 100 feet of raceway; less fall is needed for longer raceways. When the ground is ready and supply and drain lines are installed, pour the concrete foundation to the desired thickness. Before the concrete has set, place on it the spiraled pipe and depress about 0.5 inch. This will make a groove to receive the lower edge of the raceway wall. When the concrete has hardened, remove the pipe and attach it to the upper rim of the wall. Then place the whole assembly on the foundation, with the lower edge in the groove. Use 2 by 4 timbers to hold the assembly in position until fresh grout--about 1 inch thick, troweled very smooth--has been spread on the floor to seal edges and correct any irregularities in elevation.

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AN IMPROVED 150-GALLON FISH-PLANTING TANK

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AN IMPROVED 150-GALLON FISH-PLANTING TANK, designed and built by Ernest Murphey and Al Reese of the California Department of Fish and Game, has been extensively tested during the past year. Loads of as much as 500 pounds of rainbow trout that ranged from 3.8 to 19 per pound were held as long as 7 hours with excellent results. No delayed loss was observed in fish held for observation after release from the tank.

Tests included planting fish under normal and extreme operating conditions. Trout were transported over desert roads during periods of high temperature. The tank was operated without loss of efficiency at altitudes exceeding 7,000 feet.

In designing the tank, it was recognized that the capacity of the standard 150-gallon aspirator-aerated tank (Leitritz 1950) was limited to about 300 pounds of trout, even when hypnotic drugs were added. Reasons advanced for this were excessive turbulence, piling up of fish on the bottom of the tank, dead-water areas, inefficient mixing of the air introduced by the aspirator, and difficulty in dissipating waste products from a closed aspirator aeration system.

Correction of these supposed shortcomings led to a shallow tank, aerated by a modified aspirator and spray system. Features of the tank are diagrammed in figure 1.

The spring-loaded lid permits easy access to the tank. Perforated plate baffles, attached to the lid, lift out of the tank when the lid is opened and are intended to prevent excessive water surge. The baffles are spaced 6 inches from the lid, in order not to interfere with the spray.

Water is drawn from four evenly spaced points on the bottom of the tank. It is circulated through an aspirator and discharged through horizontal spray nozzles at the top of the tank (figure 2).

The spray system differs from the conventional spray system. In order to avoid turbulence and promote dissipation of gases and unmixed air, the water is sprayed across the top of the tank. Nozzle pressure is maintained at about 4 pounds. It is important not to exceed this pressure, because every added pound of nozzle pressure further reduces the efficiency of the aspirator. Nozzle openings are adjusted to maintain the proper pressure.

A portion of the unmixed air introduced by the aspirator is trapped at the high point in the discharge line and returned to the suction line at the pump bowl. The pump impeller mixes the air and water at the time the oxygen content of the water is lowest. Two vents in the top of the tank provide for the escape of gases and excess air.

A 1.5-inch centrifugal pump (figure 3) completely circulates the water in the tank every 1.5 minutes. Dye introduced through the aspirator has shown rapid diffusion throughout the tank, with no dead-water areas.

To keep fish from piling up and smothering on the bottom of the tank, water depth is held to 13 inches at all times. This is 2 inches below the top of the tank, exclusive of the lid flange. This level

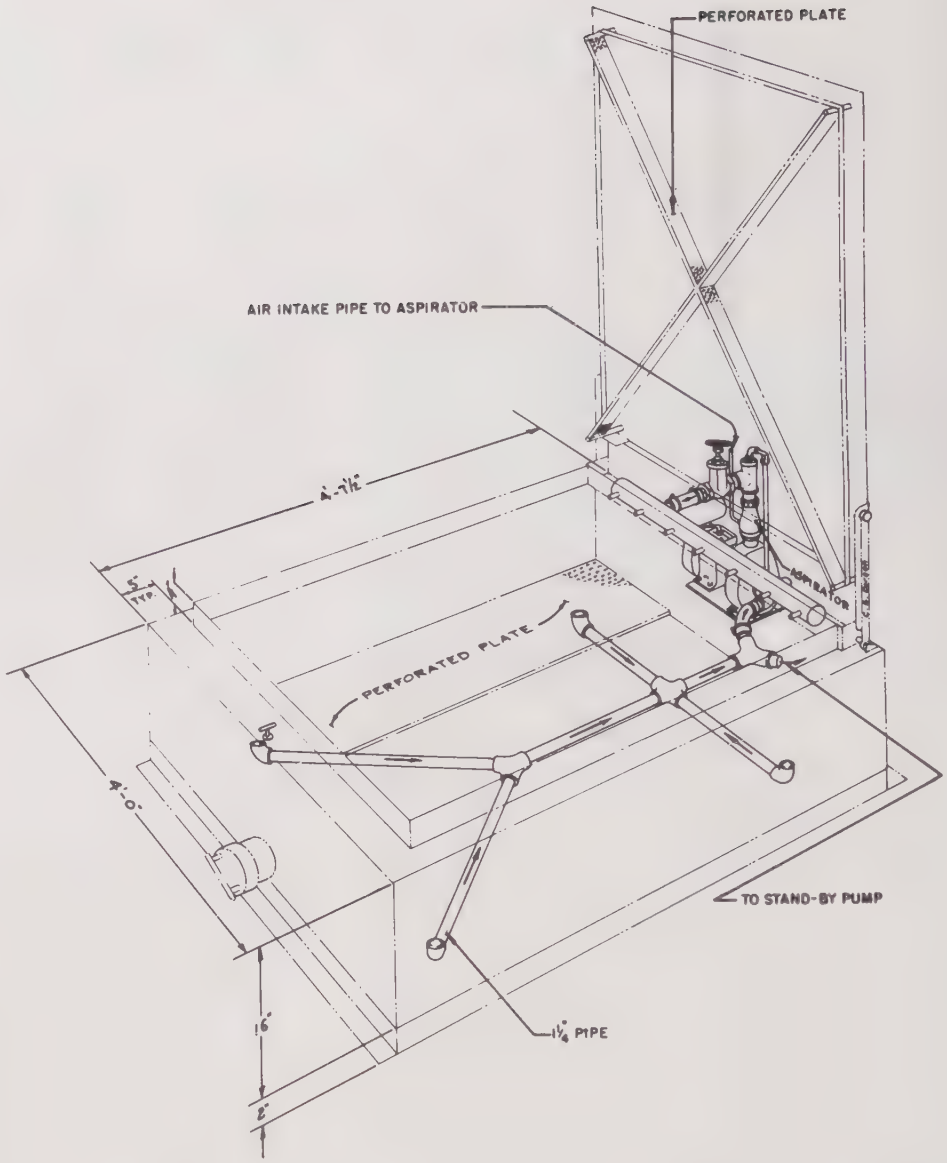

FIGURE 1.--Water circulating system: a 150-gallon fish-planting tank.

provides a maximum surface area to spread the spray and allow surface dissipation of gases.

Table 1 shows the results of the first test. The standard aspirator-aerated tank was loaded with 300 pounds of trout, without hypnotic drugs, as a control. It was necessary to release the fish in the control tank at the end of 3 hours. As this confirmed many previous tests, no controls were run on subsequent tests.

The 350 pounds of trout placed in the experimental tank were held for 6 hours and were in excellent condition when released.

The results of subsequent tests are presented in table 2. Consistently good results were obtained with 500-pound loads. Loads in excess of 500 pounds, held for any length of time, usually resulted in excessive losses. Although a 600-pound load was held successfully for a short time, 500 pounds appeared to be the maximum safe load.

The use of drugs had no effect on the carrying capacity of this tank. Without drugs, however, it is practically impossible to carry more than 200 pounds of trout longer than 3 hours in the standard tank.

Results of tests with trout averaging 17 and 19 per pound indicate the possibility of increased efficiency in tank transportation of fingerlings. The tank has not been tested with smaller fish.

To determine the reason for the increased efficiency of the experimental tank, one of the standard tanks was converted to the same type of circulation system. The water depth of the converted tank was 22 inches, compared to 13 inches

FIGURE 2.-- Tank with lid raised, showing baffle arrangement and horizontal spray.

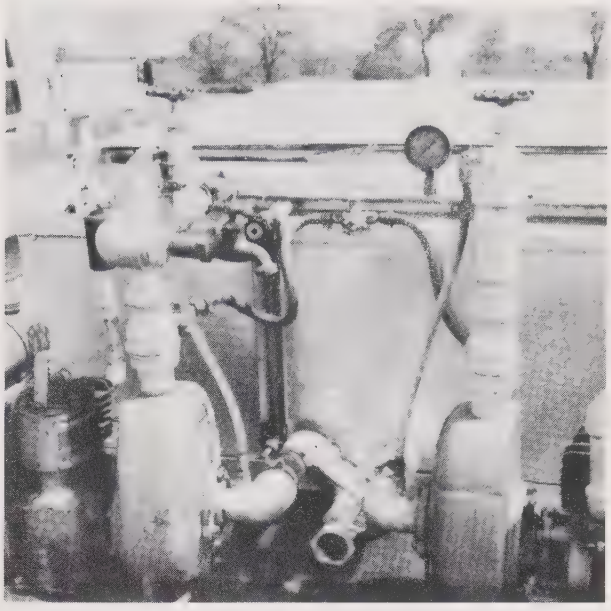

FIGURE 3.-- Pumps and plumbing arrangement, showing unmixed-air return tube to suction side of pump. One pump is operated at a time; the other pump serves as a standby.

for the experimental tank. No vents, other than seepage around the lid, were provided for the escape of gases and unmixed air. The air return lines to the pump bowls were blocked off.

Results of these tests are shown in table 3. Carrying capacity of the converted tank was 450 pounds of trout in a total volume of 140 gallons. This compares very favorably with the capacity of 500 pounds of trout in 150 gallons for the experimental tank.

Water depth within the limits tested and elimination of the air return to the pump bowl did not materially affect the carrying capacity.

From these tests, it appears that the most important feature of the experimental tank is the rapid circulation of water without excessive turbulence. This is further borne out by the performance of the tank with smaller fish.

The tank used was an experimental tank; certain refinements, such as a sight glass, observation windows, and simplified piping, are needed for a production model. Moreover, the water temperature increased more rapidly in the experimental tank than in the standard tank. This can probably be overcome by insulation.

TABLE 1.--Control test

Type of tank	Pounds of trout	Number of trout per pound	Hours held in tank	Hypnotic drugs used?	Antifoam used?	Average water temperature (° F.)	Loss
Experimental---	350	6.2	6 1/	No	Yes	49	1
Standard-------	300	6.2	3 1/	No	Yes	48	16

1/Fish in distress when released.

TABLE 2.--Planting tests of experimental tank

Name of hatchery	Date	Pounds of trout	Number of fish per pound	Hours held in tank	Hypnotic drugs used?	Antifoam used?	Average water temperature (° F.)	Loss	Condition of fish
Darrah Springs	4/ 4/57	400	6.2	6	No	Yes	48	1	Good.
	4/ 9/57	450	6.7	4	No	Yes	47	8	Good.
	4/10/57	450	6.9	6	Yes	Yes	47	21	Fair.
Fish Springs	8/30/57	450	3.8	3	No	No	48	0	Good.
	9/12/57	500	3.8	4	No	No	49	1	Good.
	9/18/57	500	3.0	5	No	No	50	0	Good.
Mojave River	10/28/57	400	4.0	2.5	No	No	48	3	Good.
	10/29/57	450	4.0	3.5	No	No	52	0	Good.
	10/30/57	550	3.9	2.5	No	No	53	2	Good.
	10/31/57	500	4.0	3.5	No	No	52	3	Good.
	11/ 5/57	600	3.8	3	No	No	45	0	Good.
	11/ 7/57	600	3.7	4	No	No	54	3	Good.
	11/ 8/57	750	4.4	2	No	No	50	15	Pump stopped. Fish released in distress.
San Joaquin	1/ 6/58	500	4.5	5	Yes	Yes	46	0	Good.
	1/ 7/58	500	4.5	7	Yes	Yes	47	6	Good.
	1/ 9/58	500	4.5	5	Yes	Yes	45	5	Good.
	1/30/58	400	17.0	6	Yes	Yes	46	4	Good.
	2/11/58	500	19.0	5.5	Yes	No	46	5	Good.
	2/13/58	700	5.0	4	Yes	Yes	43	165	Fish in distress.
	2/14/58	600	5.0	4	Yes	Yes	44	100	Fish in distress.

TABLE 3.--Tests of converted standard tank at San Joaquin hatchery

Pounds of trout	Number of trout per pound	Hours held in tank	Hypnotic drugs used?	Antifoam used?	Average water temperature (° F.)	Loss	Condition
400	5.0	3	Yes	Yes	43	0	Good.
500	5.4	4-1/4	Yes	Yes	45	200	Poor.
500	5.0	5-1/4	Yes	Yes	44	160	Poor.
450	5.2	5-1/6	Yes	Yes	43	2	Good.
450	5.0	5	Yes	Yes	45	0	Good.

The tank nearly fills a 0.75-ton pickup truck bed, leaving little room for ice or equipment. However, the tank will fit crosswise on a 0.75-ton flatbed truck, leaving plenty of room for ice and equipment.

Five hundred pounds of trout will displace about 62.5 gallons of water, leaving about 87.5 gallons of water in the tank after the fish are loaded. Allowing for the amount of water displaced, the carrying capacity of the tank is 5.7 pounds of trout per gallon of water, without drugs. On the same basis, the capacity of the standard tank is 2.1 pounds of trout per gallon of water.

For every gallon of water transported, the amount of trout that can be carried is nearly triple that carried in our present equipment.

Literature Cited

Leitritz, Earl
1950. Fish-planting tank for 3/4-ton pickup truck. Prog. Fish-Cult. 12 (4): 197-206.

NATIONAL SCIENCE FOUNDATION'S CLOSING DATE FOR RECEIPT OF BASIC RESEARCH PROPOSALS IN THE LIFE SCIENCES

The Division of Biological and Medical Sciences of the National Science Foundation announces that the next closing date for receipt of basic research proposals in the life sciences is May 15, 1959. Proposals received prior to that date will be reviewed at the summer meetings of the Foundation's advisory panels and disposition will be made approximately four months following the closing date. Proposals received after the May 15, 1959, closing date will be reviewed following the fall closing date of September 15, 1959.

Inquiries should be addressed to the National Science Foundation, Washington 25, D. C.

Mr. Lewis R. Garlick, Chief of the Division of Sport Fisheries for Region 2 (Albuquerque, New Mexico), Bureau of Sport Fisheries and Wildlife, is a direct descendant of Dr. Theodatus Garlick, who published in 1857 the first American book on fish culture and is recognized as the founder of American fish culture.

DRY DIETS FOR CHINOOK SALMON

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THE PURPOSE OF THIS PAPER is to present the results obtained with seven different diets used as starting diets for chinook salmon fry.

Materials and Methods

The fish for this experiment were obtained as eggs from the State Department of Fisheries at Issaquah, Washington, and hatched at the College of Fisheries, University of Washington, Seattle, Washington. Into each of 7 troughs, 1,000 chinook salmon fry were hand-counted. Initial average weight per fish was obtained by weighing 100 fish from each of the troughs. Lengths were determined by drawing 50 fish through a glass tube and measuring them with dividers. Fish dying with white-spot disease were replaced prior to the initial feeding date.

The water used was well water supplemented with water pumped from Lake Washington. During the 10 weeks of feeding, water at a temperature of 52° to 53° F. flowed through the troughs at the rate of 1.75 gallons per minute, which amounted to 2.3 water changes per hour.

The troughs were made of concrete, approximately 15 feet long, 12 inches wide, and 8 inches deep. An average water depth of 5 inches was maintained in each trough.

The diets for the seven lots of fish were as follows:

Lot 1. -- 40% beef liver, 60% fish meal
Lot 2. -- 40% beef liver, 60% shrimp meal
Lot 3. -- 50% fish meal, 50% shrimp meal
Lot 4. -- 100% X, a commercial fry feed (pelleted)
Lot 5. -- 100% Y, a commercial fry feed (pelleted)
Lot 6. -- 100% Z, a commercial fry feed (pelleted)
Lot 7. -- 100% fish meal

For a week prior to the initial feeding date, all of the test fish except lots 4, 5, and 6 were fed a diet consisting of fish meal prepared from mixed marine fish. The fish meal was produced from fish caught locally in Puget Sound and processed into meal at the College of Fisheries. The method of processing the fish meal is an important factor in determining its efficiency as a feed. The marine fish were put in a vacuum drier with 1 percent oat flour added to retard rancidity. The temperature was kept below 170° F. When the moisture content was reduced to 5 percent, the meal was removed and finely ground in a mill.

Frozen shrimp from Alaska were processed into meal by the Technology Laboratory, Bureau of Commercial Fisheries, in Seattle. The three commercial pellets were supplied by the producers.

The beef liver was fresh, and it was ground several times through a fine plate in a chopper.

Diets for lots 1 and 2 were mixed in a pan by spoon until thoroughly blended. The diet for lot 3 consisted of equal parts of fish meal and shrimp meal mixed well and then ground three times through a

mill. The four other diets were fed as received.

Procedure

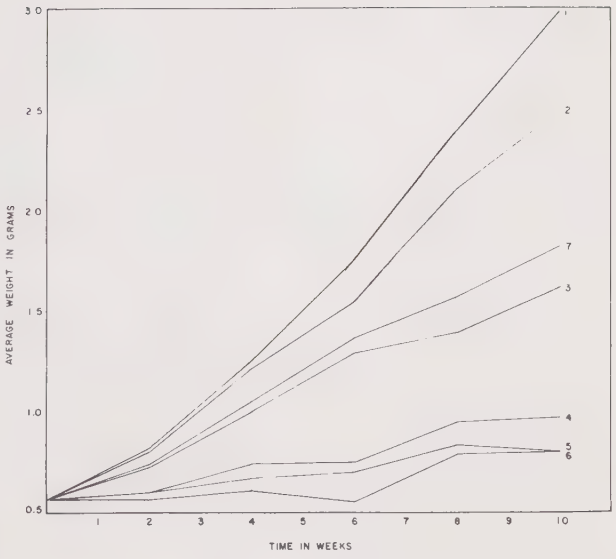
The fish were fed 8 times a day during the first week of feeding. With the start of the second week, the number of feedings for lots 1, 2, 3, and 7 was reduced to 4 a day because these fish did not appear to be getting enough feed per feeding. Lots 4, 5, and 6 were fed the commercially prepared diets 8 times a day throughout the 10 weeks of feeding. All of the lots were fed approximately 2 percent of the body weight of the fish in lot 1 per day. A 2-day supply of feed was weighed on a gram scale for each lot and kept in a refrigerator until used. All of the lots were weighed and measured every 2 weeks. The amount of feed was increased every other day for the first 2 weeks and then increased on the average of once a week as needed to coincide with the weight of the control lot of fish.

Evaluation of Results

The results of this experiment are shown in tables 1, 2, and 3.

The fish in lot 1, which were fed 40 percent beef liver and 60 percent fish meal, produced the greatest weight increase (423 percent) and had the lowest mortality (6.4 percent) for the 10-week period of the experiment. (See figure.)

Lot 2, fed 40 percent beef liver and 60 percent shrimp meal, had a gain of



Comparison of average increase in weight of chinook salmon fingerlings fed on seven diets. No. 1 is the control diet.

337 percent in weight and a loss of 6.8 percent (excluding 136 mortalities due to mechanical failure). This would indicate that the shrimp meal was not so satisfactory as the fish meal in this test.

The diet of 50 percent fish meal and 50 percent shrimp meal, fed to fish in lot 3, showed a deficiency after 6 weeks. This was manifested by the high mortality of fish having clubbed gills.

The fish in lots 4, 5, and 6 would not eat the dry pellets. When being fed, the fish would take a particle of the food in the mouth and then "spit" it out. It is thought that the food was either too

TABLE 1.--Cumulative mortality data for seven lots of chinook salmon (1,000 per lot) fed experimental diets from February 3 to April 14, 1958

2-week intervals	Mortalities						
	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7
1 -----	30	36	34	35	30	36	34
2 -----	46	54	45	59	47	56	51
3 -----	48	62	56	63	49	63	60
4 -----	55	1/ 203	366	79	77	75	93
5 -----	64	204	749	166	278	104	527

1/ 136 of these mortalities were due to mechanical failure.

TABLE 2.--Average weight (in grams) of chinook salmon fingerlings, based on samples weighed at 2-week intervals

Date weighed	Average weight (in grams)						
	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7
Feb. 3	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Feb. 17	.82	.80	.73	.60	.60	.57	.74
Mar. 3	1.25	1.21	1.00	.74	.67	.61	1.05
Mar. 16	1.74	1.56	1.29	.75	.70	.55	1.37
Mar. 31	2.39	2.10	1.38	.95	.83	.79	1.57
Apr. 14	2.98	2.49	1.62	.97	.80	.80	1.83

TABLE 3.--Summary of experimental feeding tests with chinook salmon fingerlings

Item	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7
Initial average length---cm.--	3.33	3.33	3.33	3.33	3.33	3.33	3.33
Average length at termination----------cm.--	5.75	5.57	5.12	4.35	4.31	4.21	5.07
Percentage of gain in length--	73	67	54	31	29	26	52
Initial average weight---gm.--	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Average weight at termination----------gm.--	2.98	2.49	1.62	0.97	0.80	0.80	1.83
Percentage of gain in weight--	423	337	184	70	40	40	221
Mortality----------	64	1/204	749	166	278	104	527
Percentage of mortality-------	6.4	20.4	74.9	16.6	27.8	10.4	52.7
Total weight of food fed gm.--	2,960	2,960	2,960	2,960	2,960	2,960	2,960
Pounds of food to produce 1 pound of fish----------	1.33	2.09	-----	12.4	42.2	20.2	10
Efficiency factor----------	0.74	0.47	-----	0.08	-----	0.05	0.10

1/ 136 of these mortalities were due to mechanical failure.

hard or not palatable. Most of the fish in these three lots were pinheaded and snaky.

The fish in lot 7, which were fed 100 percent fish meal, appeared to be in good condition during the first 8 weeks of the experiment, having a fair gain in weight and a low mortality rate. After the eighth week these fish showed definite symptoms of some deficiency, with proliferation of the gill epithelium and convulsions which were noticeable when the trough covers were removed. During these convulsions the fish would dart from side to side, twisting and whirling about. The mortality at this time was extremely high.

Summary

1. Seven diets were tested as starting feeds for chinook salmon.

2. At the end of 10 weeks' feeding, only the diets with fresh liver proved satisfactory. The diet of fish meal and liver was superior to the shrimp meal and liver.

3. A deficiency in the diet containing 50 percent fish meal and 50 percent shrimp meal resulted in 74.9 percent mortality.

4. A deficiency in the 100-percent fish meal diet became apparent in the eighth week, resulting in 52.7 percent mortality.

5. The commercial pellets tested were unsatisfactory as starter feeds for chinook salmon.

TERRAMYCIN AS A CONTROL FOR FIN ROT IN FISHES

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FIN OR TAIL ROT, A BACTERIAL DISEASE IN FISH, is extremely troublesome when warm-water fishes are brought into a laboratory or are placed in holding pens where there is a tendency toward crowding. Bait minnows that are being held for sale, experimental fishes that are being used for life-history studies or bioassay in laboratories, and planting stock are likely to develop fin rot and either die or become useless because of the infection.

Various treatments have been recommended and tried. Some of the treatments slow or even cure the disease, but usually the recovery is slow and the fish that survive are undesirable for use.

Davis (1953) suggested dipping the fish in copper sulphate. Eicher (1947) recommended malachite green in the place of copper sulphate. He further suggested that formalin and malachite green be used to disinfect all the containers in which infected fish had been kept. Axelrod and Schultz (1955) suggested the use of acriflavine, silver nitrate, and potassium dichromate treatments, which require painting or dipping. They also mentioned aureomycin, terramycin, and chloromycin as being specific for the type of bacteria causing the disease.

During the past 5 years several experiments have been conducted to prevent the disease or to effect a cure. Because of the time involved in treating individual fish and their infected areas with a brush or swab, attention was given antibiotics. The fish first used were Hybognathus spp., which were obtained from minnow dealers. Some of the specimens were so badly infected that the posterior half of the body was paralyzed. Usually such specimens would die within 2 to 5 hours.

First, aureomycin and streptomycin were placed in the fish food and later in the water of the aquaria--to no avail. New cases of infection were found in the water treated with both antibiotics. Next, terramycin was tried. The reaction was almost immediate. No fish in the aquaria died from fin rot after the first treatment, and 48 hours later all fish were behaving normally--or at least as normally as a scarred fish can behave. Specimens that had lost their caudal fins and apparently a few caudal vertebrae were swimming about actively and seemed to be in good health.

Considerable effort was expended to learn the dosage necessary to bring about a cure. At first, the terramycin was mixed with the food, which had to be dropped into the water. Next, it was added to the aquarian waters without food. The results were the same. We were unable to divide a tablet of 100 milligrams into fractions small enough so that the smallest particles would not effect a cure.

Later, in 1955, this treatment was applied to Gambusia affinis being used as bioassay animals by Dr. I. E. Wallen. [1] Dr. Wallen was experiencing extreme difficulty with G. affinis and fin rot. Fish for bioassay need to be kept in healthy condition in the laboratory for 2 weeks

[1] Formerly associate professor of zoology, Oklahoma State University.

before use. Once the aquaria and handling equipment had become contaminated, he was losing 100 percent of the fish. Twenty-four hours after the initial treatment with terramycin, however, all fish had recovered; and as long as the water was kept treated, there were no more deaths that were known to be due to fin rot.

In 1957, Dr. T. C. Dorris[2/] had the same trouble with Pimephales promelas, which was likewise being used as a bioassay animal. The fish were infected in the pond where they were grown; and as soon as they were removed to the laboratory, the disease became epidemic. Terramycin in the water controlled the disease completely.

[2/]Assistant professor of zoology, Oklahoma State University.

Chloromycin has not been tried. To our knowledge, it was not available when terramycin was first used; and since terramycin produced an effective cure, the search for new chemicals was stopped.

Literature Cited

Davis, H. S.
1953. Culture and diseases of game fishes. 332 pp. Univ. Calif. Press, Berkeley.

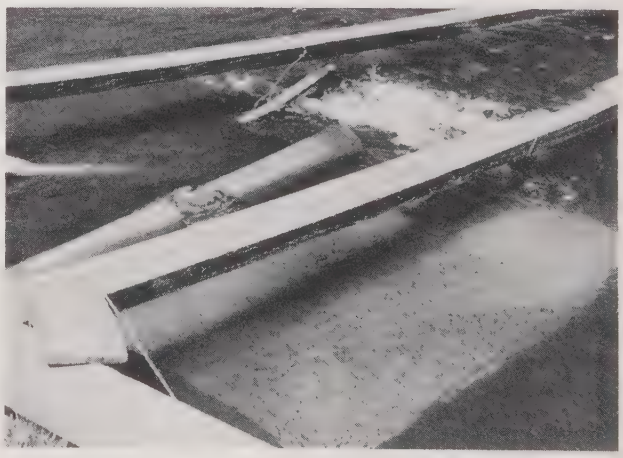
Eicher, G. J., Jr.
1947. Dual treatment for bacterial fin rot. Prog. Fish-Cult. 9 (2): 94-95.

Axelrod, H. R., and Schultz, L. P.
1955. Handbook of tropical aquarium fishes. 718 pp. McGraw-Hill, New York.

ARTIFICIALLY FED LARGEMOUTH BASS FINGERLINGS

On April 1, 1958, pond 2 of the U. S. Fish-Cultural Station at Lyman, Mississippi, was stocked with 1.5 million (estimated) largemouth bass fry, just off the nests. This pond, less than an acre in size, had been fertilized; its water was received through an 8-inch terra cotta pipe from the 20-acre pond 1, which contained the station's bluegill brood stock.

On April 4, when an overflow from pond 1 was introduced, the fry in pond 2 began to congregate at the intake to feed on the abundant natural food. A masonite chute was attached to the pipe to spread the inflow and create two large whirlpools. Frozen blocks of a mixture of dry fish food and water were placed in the inflow so that they broke gradually into small particles which remained suspended in the whirlpools. Given sparingly at first, the food eventually was taken so rapidly by the fry that the feeding process became a continuous operation between daylight and dark.



On April 14, about 1,036,000 small bass (0.75 inch) were taken from pond 2. By April 28, when it was drained, 465,500 more fingerlings were removed.

--- DUDLEY B. HEILIGER, Bureau of Sport Fisheries and Wildlife, Lyman, Mississippi.

AN INEXPENSIVE RE-CIRCULATING SEA-WATER SYSTEM

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SOME PHASES OF THE WORK carried on by the Bureau of Commercial Fisheries at Galveston, Texas, require the use of facilities for holding shrimp and other marine animals for experimental use. In the absence of a running sea-water system, a re-circulating system is a desirable substitute to keep the animals in the best possible condition. The disadvantages of using water pumps, standpipes, and other equipment containing metal in such a system are well known to workers in the marine field. Certain metallic ions are extremely toxic to some organisms. Corrosion, moreover, is a serious problem.

With the recent development of polyethylene, a relatively inert material, we were able to construct--almost completely from standard polyethylene items--the re-circulating system described here. The complete lack of contact of any metal with the water makes the system especially suitable for marine work. A simple method of waterproofing tanks for use as aquaria is also described.

The system, shown in figure 1, consists of three holding tanks, a reservoir tank, a water pump, and a filtering unit. The animals are placed in the holding tanks, which are set above the reservoir tank. Water is pumped from the reservoir tank to each of the holding tanks and to the filtering unit. From the holding tanks and filtering unit, the water drains directly back into the reservoir by means of a standpipe, thus completing the circuit.

The holding tanks were made from 3/4-inch marine plywood. Each tank measures 4 feet long, 2 feet wide, and 1 foot high, and has a capacity of 60 gallons. The tanks were waterproofed by coating them with Fiberglas resin commonly used in repairing boats. For bonding purposes, the use of unpainted wood in making the tanks is recommended. The resin is ordinarily used in conjunction with Fiberglas cloth for added strength. One tank was lined completely with Fiberglas cloth and resin, but we felt that the added strength was unnecessary and did not justify the higher cost. Instead, Fiberglas-cloth tape, 3 inches in width, was applied to the inside seams of the tanks to reduce the chances of developing leaks. If the tanks are well made with glued dado or rabbet joints, the tape can probably be eliminated. The resin is easily applied with a paint brush, and several coats are recommended. After drying, the surfaces are smooth and easy to clean.

The standpipe unit (figure 2) was constructed from integral parts of a polyethylene sink trap. The unit consists of a standpipe, an outlet flange, and a flange locknut.

Standpipes used in marine aquaria are generally made of Pyrex pipe, which is expensive, subject to breakage, and difficult to cut to size without special equipment. The polyethylene standpipe is inexpensive, practically unbreakable, and easy to cut with a hacksaw or sharp knife.

The outlet flange and flange locknut, when used, are generally made of metal. In time, corrosion sets in and the units are virtually "frozen" to the tank. Besides adding no metal to the water, the

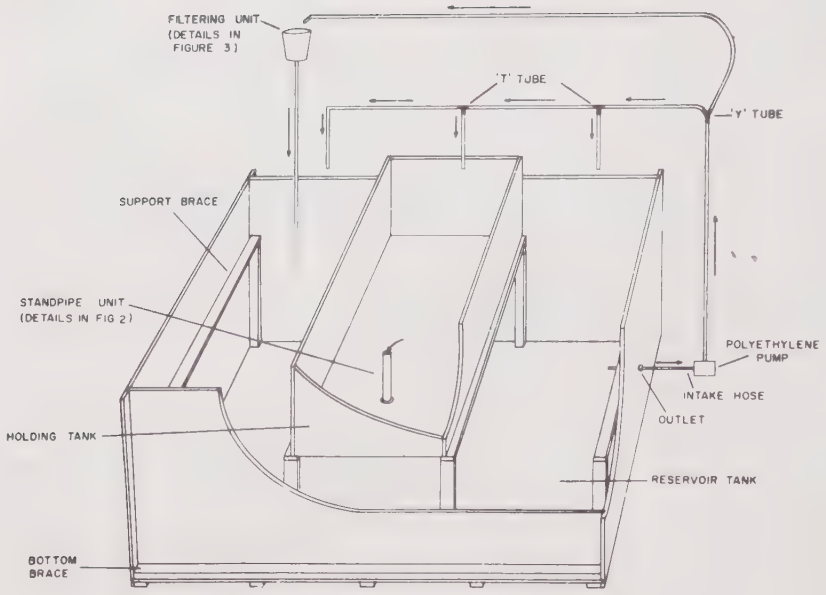

FIGURE 1.--Re-circulating sea-water system. The reservoir tank and a holding tank are cut to show construction details. Two holding tanks are not shown. Arrows indicate direction of water flow.

polyethylene components are easily installed by hand and are equally easily removed. They appear to have an indefinite life and may be particularly suitable in hatchery operations.

To install the standpipe unit, the outlet flange is inserted in a hole (2 inches in diameter) drilled in the bottom of the holding tank. The hole should be drilled prior to the application of the Fiberglas resin. The flange locknut is fastened to the outlet flange on the underside of the tank to form a watertight seal. The standpipe for maintaining a constant water level is set in the outlet flange. Stopper plugs and removable strainer inserts are also available to fit the outlet flange.

The reservoir tank (figure 1) was made primarily of 3/4-inch marine plywood. The braces along the bottom of the sides were made of 2-inch by 2-inch lumber. Five lengths of 2-inch by 4-inch lumber were attached to the bottom of the tank to raise the tank off the floor. All joints were dadoed and glued. The tank measures 6 feet long, 4 feet wide, and 4 feet high, and has a capacity of more than 700 gallons. In our construction, 2-inch by 4-inch braces for supporting the holding tanks were attached to the inside of the reservoir tank, slightly below the top. The holding tanks rested partly within the reservoir tank, so that the capacity of the latter was reduced to about 550 gallons. Waterproofing was accomplished by use of Fiberglas resin and tape.

A hole 2 inches in diameter was drilled in one end of the reservoir tank to provide an outlet. The outlet was tapped about a foot from the bottom in order to avoid sucking up accumulated silt on the bottom of the tank. Polyethylene tubing was connected from the outlet to a water pump which distributed water to each of the three tanks. Aeration was accomplished by jetting the water into each of the tanks. Another line from the pump led to a filtering unit. Water drained through the filter directly into the reservoir tank at the end opposite the outlet.

The outlet from the reservoir tank can be eliminated by placing the intake hose directly in the reservoir tank; but in case of intermittent power failure, the pump will lose its prime and it may be damaged seriously.

We made use of a centrifugal-type pump, powered by a 1/35-hp., 3,000-r.p.m. motor,

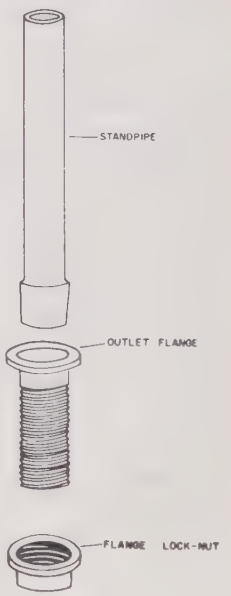

FIGURE 2.--Standpipe unit.

that was capable of effecting a flow of 45 gallons per hour in each tank and in the filter. The unit is compact, measuring approximately 6 inches by 4 inches by 4 inches. In operation, it is very quiet. Most important of all, both the pump head and the impeller are made of polyethylene.

The filter (figure 3) was made primarily from polyethylene items available in many stores and found commonly in kitchens. Small holes were drilled in the bottom of a small polyethylene wastebasket, and the bottom was lined with a piece of saran screening. A 2-inch layer of activated charcoal was placed on top of the saran. A colander containing glass wool was nested on top of the wastebasket. The entire unit was then placed in a larger container that had an outlet tapped in the bottom for the filtered water to drain into the reservoir.

This re-circulating system has proved highly satisfactory. Fish, postlarval and adult shrimp, and other invertebrates have been held indefinitely in the tanks without appreciable mortality. The cost of the apparatus is considered relatively inexpensive, amounting to slightly more than $100.

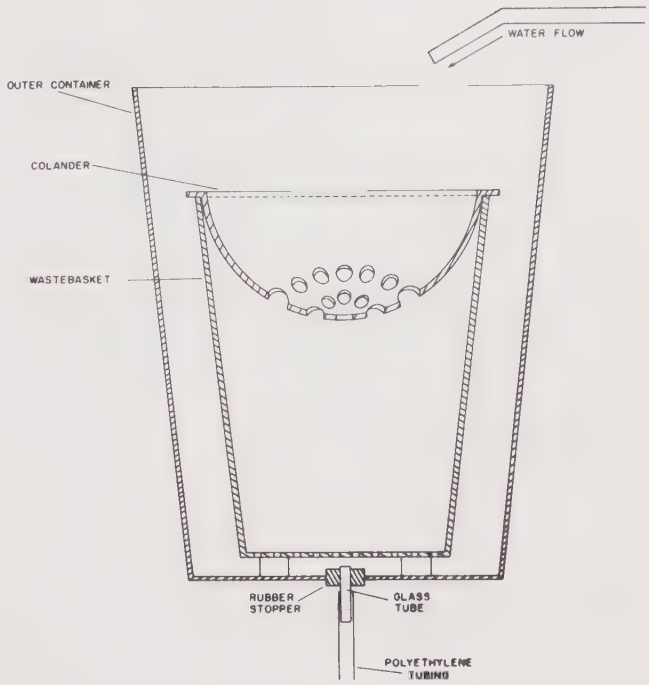

FIGURE 3.--Filtering unit.

TROUT - DISTRIBUTION MAP OF THE NORTH ISLAND OF NEW ZEALAND

The factors limiting the distribution of trout in the North Island of New Zealand have been summarized and charted by K. Radway Allen in the October 1958 issue of Ammohouse Bulletin.

Streambeds in parts of the northern arm, in the northwestern section, and along the eastern coast are covered with geologically young rocks that do not provide the gravels necessary for spawning grounds. Most of the rocks of volcanic origin--which form good gravels for trout regardless of age--occur in the central part of the island.

In a few areas the land is too flat to give flows suitable for trout. Although these fish have established themselves in North Island streams that are much more quiet than those used elsewhere by trout, the limit seems to be a gradient of about 1 in 1,000.

The northern extremities of the North Island are shown to have temperatures averaging above 50° F. during the winter months. As there are no trout in this part of the island--even in those areas where other conditions seem suitable for the species--it is possible that winter temperatures above 50° F. are too high for successful spawning.

A fourth factor in the paucity of trout fishing on the North Island is inaccessibility, and the trout-distribution map of the island shows areas where the rivers are too far from roads and therefore are almost unused.

DIVIDENDS FROM RESEARCH

POND RESEARCH AND BAIT PRODUCTION IN MINNESOTA

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Sport fishing in Minnesota is a 100-million-dollar industry. Every year more than 1 million people wet their lines in quest of a fine string of sporty fish. A large percentage of these fishermen prefer to bait their hooks with minnows and white suckers. Consequently, the capture and sale of bait fishes has become big business. In 1956 about 3,300 dealers were licensed to sell live bait in Minnesota.

During the past 15 years research has aided greatly in the development of the bait-fish industry. Prior to that time nearly all bait fishes sold were seined from public waters. During the drought years of the thirties, water levels were very low and minnows--especially the preferred stream minnows--were concentrated in shallow pools where they were caught easily by seiners. As a result, minnows of suitable size for walleye fishing became scarce. A few dealers sought a solution to the problem in fish farming but were not very successful. Too little was known about the requirements of bait fishes, propagation, and rearing methods.

To meet the growing need for a more certain supply of these fishes, biologists and fish-culturists of Minnesota, Michigan, Wisconsin, and the U. S. Fish and Wildlife Service pooled their investigative efforts and information and, as a result, brought out a bulletin on minnow propagation ("Propagation of Minnows and Other Bait Species" by Dobie, Meehean, and Washburn, U.S.D.I. Circular 12, published in 1948, revised in 1956) in order to make current information available to dealers and to point out to research men the phases of the work requiring more study. This bulletin has been distributed widely among those who rear bait fish; but even before it was off the presses, the cooperating agencies had begun an extensive program of pondfish research.

In Minnesota the Fisheries Research Unit made a 5-year study of sucker ponds to determine the type of pond most suited to sucker propagation, the relationship between sucker growth and population size, pond fertilizer requirements, and harvest dates for pike-size bait fish. As a result of the information made available to bait dealers from these studies and the aid given to the dealers by State personnel, about 75 private hatcheries have been established in Minnesota for the propagation of minnows and suckers. In 1957, 42 operators came to the State-supervised sucker-stripping stations to collect 233,764,000 eggs which were hatched in their own batteries. The fry (111,234,280) were stocked in 453 ponds to produce 13,595,000 pike-size bait fishes. Fry stocked in ponds in May will produce 3.5-inch fish by mid-July. The smaller fish from overcrowded ponds are held overwinter to be placed in growing ponds in May. These fish are large enough to be sold in June. Many dealers operate this system on a scale large enough to provide themselves with a year-round supply of walleye pike bait. Crappie bait, mostly fathead minnows, is still obtained from shallow prairie lakes. The suckers are reared in moderately fertile ponds--the best of which fluctuate

somewhat in water-level--and usually are reared without fertilization. A wise choice of ponds is the key to success. Most dealers hedge on their guesses by using a variety of ponds each year.

Research on sucker propagation alone has resulted in a large industry of great value to the State. Dealers who were skeptical at first are now fully convinced of the value of pond-reared fish, and few would care to revert to the cutthroat days of seining in public waters.

NEW SHRIMP FISHERY OF THE PACIFIC NORTHWEST

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In 2 years, a thriving shrimp fishery has developed off the coasts of Washington and Oregon. This new industry is a direct result of systematic exploratory fishing by the Bureau of Commercial Fisheries in cooperation with the two State fishery agencies.

Washington shrimp landings exceeded 2 million pounds in 1957, the first full year following the initial explorations. Fishermen landed more than 4.5 million pounds of shrimp in the State during the first 6 months of 1958. Substantial landings of shrimp are now being made also in northern Oregon. Prior to 1956, no offshore shrimp fishery existed in either State.

A combination of factors in addition to the exploratory research accelerated the development of the fishery. Immediately after release of research results defining the location and the availability of the shrimp to various types of gear, the automatic shrimp-peeling machine was introduced into the area--at a time when the Gulf Coast pack of canned shrimp was extraordinarily small. Availability of the raw product, mechanization to eliminate costly hand labor, and a good market enabled several far-sighted operators to build an industry practically overnight.

In June 1958, about 30 shrimp vessels were delivering their catches to plants in southwest Washington and northwest Oregon, which were operating 10 automatic peeling machines. Catches were averaging about 8,000 pounds a day per boat during good fishing weather. Practically the entire catch was being canned.

The shrimp exploratory program was planned in 1955 in response to requests from fishing-industry members. Several operators of crab plants in the Grays Harbor area of Washington asked the Bureau to investigate the shrimp resources in adjacent offshore waters as a possible source of business during the off-season for crabs. Fishermen had known for years that shrimp were present on the continental shelf along the Pacific coast, but their relative abundance off Washington and the most efficient gear for commercial operations were not known. In northern California a small beam-trawl fishery for shrimp had operated for several years on beds discovered by State research vessels. Successful shrimp explorations off the Oregon coast in 1951 and 1952 by the Fish Commission of Oregon, using a beam trawl, indicated that the largest concentrations of shrimp were taken in areas of green-mud bottom at depths between 60 and 80 fathoms. Commercial development of these grounds did not follow because of lack of a profitable market at that time.

With this background information, two cruises were conducted with the Bureau's exploratory fishing vessel John N. Cobb, the first in the fall of 1955 and the second during the spring of 1956. The area of coverage extended about 100 miles along the Washington coast, between Destruction Island and Long Beach, and 31 miles offshore (the approximate maximum width of the continental shelf). During the fall exploration a 20-foot Alaska-type beam trawl and a small 45-foot otter trawl were used. For the following spring trip, the gear experts obtained a 40-foot flat shrimp trawl from Mississippi for extensive experimentation. As far as is known, this was the first time a Gulf of Mexico shrimp trawl was used on the Pacific coast.

Fishing results during the fall (1955) exploration revealed that pink shrimp (Pandalus jordani) were widely distributed at various depths over the entire area explored. The spring (1956) exploration demonstrated that the Gulf shrimp trawl was by far the most efficient and practical type of gear for taking shrimp on these grounds. Of the 51 drags made with this gear, 25 produced shrimp in amounts ranging from 300 to 2,200 pounds per hour. Several highly productive localities were found and explored intensively. Best catches were made at depths from 70 to 80 fathoms on green-mud bottom, but good fishing was found at various depths between 60 and 90 fathoms. Seven 30-minute "production" drags off Copalis Head in one 6-hour period produced a total of 5,210 pounds of shrimp--excellent commercial production.

Results were made available to the public immediately; and before the John N. Cobb had completed the cruise in April 1956, one commercial shrimper was in operation on the newly discovered grounds. The fishery expanded to such an extent during 1957 that further exploration was requested in 1958. Additional productive shrimp grounds were located off Washington and Oregon during April, May, and June of this year and were immediately exploited by the fishing fleet. Biologists from the State fishery agencies cooperated on the cruises, collecting samples of shrimp for biological studies and obtaining data pertinent to regulation of the fishery.

The 1958 catch of shrimp landed in Washington totaled 4,760,000 pounds by July 1. It has been predicted that the total catch in Washington and Oregon will approach 10 million pounds this year.

TRICAINE METHANESULFONATE (M.S. 222) IN TRANSPORT OF CUTTHROAT TROUT

In July 1958 the Trailblazers Club, Inc., of Seattle, Washington, wanting a technique to narcotize small trout--and reduce the water-to-fish ratio in its planting--tested tricaine methanesulfonate (M.S. 222).

In the first trial, 20 cutthroat trout (1,200 to the pound) were put in each of 5 plastic bags (8 by 4 by 16 inches) with 200 milliliters of M.S. 222 in a concentration of 1:20,000, 1:40,000, 1:60,000, 1:80,000, or 1:120,000. The air in each bag was then replaced with oxygen. When they had been closed with rubber bands, the bags were put into a 5-gallon pack-can with 4 or 5 pounds of ice.

After a 5-hour hike to the lake, the fish were released in corrals of fine netting in shallow water. Fish still immobilized an hour later were rated as mortalities. The 1:20,000 concentration resulted in 95 percent mortality; other concentrations gave little difference in survival. Fish in the heavier concentrations took longer to recover, but all fish recovered in good shape from concentrations of 1:40,000 and less.

A week later the club tried using just 6 milliliters of the 1:40,000 solution per gram of fish (equivalent to 2.5 quarts of water per pound of fish, or an eighth of the weight of water usually carried).

Into each of four 1-quart plastic food containers of the type used in freezers, 500 milliliters of a 1:40,000 concentration of M.S. 222 was poured. About 500 cutthroat trout (3,000 to the pound) were put in each container, which was then closed tight with a friction-type cover. Oxygen was not used. The containers (each about half full) were put into an insulated "picnic bag" with about 3 pounds of ice, and the bag was placed in a pack-sack.

Three hours later the fish were released in the lake after some temperature adjustment. An hour later 19 inactive fish were rated as mortalities; the rest of the 2,000 fish could be seen feeding in the shallows 100 yards in each direction from the release point.

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TO CONTRIBUTORS

Contributions for publication in THE PROGRESSIVE FISH-CULTURIST are always welcome. All contributions should be directed to: The Editor, THE PROGRESSIVE FISH-CULTURIST, Bureau of Sport Fisheries and Wildlife, Washington 25, D. C.

Manuscripts should be typewritten, double-spaced, on one side of white bond paper. Illustrations should be in the form of sharp, glossy, black-and-white photographs or drawings prepared with waterproof black India ink on heavy white paper or tracing cloth.

A short abstract should be submitted with each manuscript. When an article has appeared in an issue of THE PROGRESSIVE FISH-CULTURIST, the publication data will be added to the abstract and this will then be forwarded to Biological Abstracts and Sport Fishery Abstracts.

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